EDITED BY

DIONYSIUS LARDNER, D.C.L.,

Formerly Professor of Natural Philosophy and Astronomy in University College, London.

ILLUSTRATED BY ENGRAVINGS ON WOOD.

VOL. VIII.

LONDON:

WALTON AND MABERLY,

UPPER GOWER STREET, AND IVY LANE, PATERNOSTER ROW.

1855.

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

CONTENTS.

THE STELLAR UNIVERSE.

COMMON THINGS—MAN.

MAGNIFYING GLASSES.

INSTINCT AND INTELLIGENCE.

THE SOLAR MICROSCOPE.

THE CAMERA LUCIDA.

THE MAGIC LANTERN.

THE CAMERA OBSCURA.

Errata in Vol. VII. of "Museum of Science and Art."

Page	43,	line	8,	*for*	"February"	*read*	"April."
,,	159,	,,	29,	,,	"December"	,,	"June."
,,	,,	,,	32,	,,	"June"	,,	"December."
,,	,,	,,	35,	,,	"summer"	,,	"winter."
,,	,,	,,	36,	,,	"latter"	,,	"early."
,,	162,	,,	23,	,,	"June"	,,	"December."
,,	170,	,,	1,	,,	"seven"	,,	"eight."

Fig. 56.*
OVAL BLUISH NEBULA, OBSERVED BY SIR JOHN HERSCHEL.

Fig. 57.*
THE SAME OBJECT, AS SHOWN BY THE GREAT ROSSE TELESCOPE.

THE STELLAR UNIVERSE.

CHAPTER IV.

58. SOME other explanation of the phenomena must, therefore, be sought for; and the illustrious observer soon arrived at the conclusion, that these apparent changes of position were due to real motions in the stars themselves; that these stars, in fact, moved in proper orbits in the same manner as the planets moved around the sun. The slowness of the succession of changes which

* See note, p. 193, vol. vii.

were observed, rendered it necessary to watch their progress for a long period of time before their motions could be certainly or accurately known; and accordingly, although these researches were commenced in 1778, it was not until the year 1803 that the observer had collected data sufficient to justify any positive conclusion respecting their orbital motions. In that and the following year, Sir William Herschel announced to the Royal Society, in two memorable papers read before that body, that there exist sidereal systems consisting of two stars revolving about each other in regular orbits, and constituting what he called *binary stars*, to distinguish them from double stars, generally so called, in which no such periodic change of position is discoverable. Both the individuals of a binary star are at the same distance from the eye in the same sense in which the planet Uranus and its attendant satellites are said to be at the same distance.

More recent observation has fully confirmed these remarkable discoveries. In 1841, Mädler published a catalogue of upwards of 100 stars of this class, and every year augments their number. These stars require the best telescopes for their observation, being generally so close as to render the use of very high magnifying powers indispensable.

59. The moment the revolution of one star round another was ascertained, the idea of the possible extension of the great principle of gravitation to these remote regions of the universe naturally suggested itself. Newton has proved in his *Principia*, that if a body revolve in an ellipse by an attractive force directed to the focus, that force will vary according to the law which characterises gravitation. Thus an elliptical orbit became a *test* of the presence and sway of the law of gravitation. If, then, it could be ascertained that the orbits of the double stars were ellipses, we should at once arrive at the fact that the law of which the discovery conferred such celebrity on the name of Newton, is not confined to the solar system, but prevails throughout the universe.

60. The first distinct system of calculation by which the true elliptic elements of the orbit of a binary star were ascertained, was supplied in 1830, by M. Savary, who showed that the motion of one of the most remarkable of these stars (ξ *Ursæ majoris*), indicated an elliptic orbit described in 58¼ years. Professor Enckè, by another process, arrived at the fact that the star 60 *Ophiuchi* moved in an ellipse with a period of 74 years. Several other orbits were ascertained and computed by Sir John Herschel, MM. Mädler, Hind, Smyth, and others.

61. The following Table is given by Sir J. Herschel, as containing the principal results of observation in this part of stellar astronomy up to 1850.

Star's Name.			Apparent semi-axis.	Excentricity.	Position of Node.		Perihelion from Node or Orbit.		Inclination.		Period in Years.	Perihelion Passage.	By whom computed.
1.		Herculis .	1·189″	0·44454	39°	26′	262°	4′	50°	53′	31·468	1829·50	Mädler.
2.		η Coronæ B. .	1·088	0·33760	24	18	261	21	71	8	43·246	1815·23	Ditto.
3.		ζ Cancri .	1·292	0·23486	1	28	266	0	63	17	58·910	1853·37	Ditto.
4.	a.	ξ Ursæ majoris	3·857	0·41640	95	22	131	38	50	40	58·262	1817·25	Savary.
4.	b.	Ditto .	3·278	0·37770	97	47	134	22	56	6	60·720	1816·73	Herschel, junior.
4.	c.	Ditto . .	2·417	0·41350	98	52	130	48	54	56	61·464	1816·44	Mädler.
5.		ω Leonis .	0·857	0·64338	135	11	185	27	46	33	82·533	1849·76	Ditto.
6.	a.	p. Ophiuchi .	4·328	0·43007	147	12	125	22	46	25	73·862	1806·88	Encké.
6.	b.	Ditto . .	4·392	0·46670	137	2	145	46	48	5	80·340	1807·06	Herschel, junior.
6.	c.	Ditto .	4·192	0·44380	126	55	142	53	64	51	92·870	1812·73	Mädler.
7.		Σ 3062 . .	1·255	0·44958	15	3	137	27	35	31	94·765	1837·41	Ditto.
8.		ξ Bootis . .	12·560	0·59374	359	59	100	59	80	5	117·140	1779·88	Herschel, junior.
9.		δ Cygni . .	1·811	0·60667	24	54	243	24	46	23	178·700	1862·87	Hind.
10.		γ Virginis . .	3·580	0·87952	5	33	313	45	23	36	182·120	1836·43	Herschel, junior.
11.	a.	Castor .	8·086	0·75820	58	6	97	29	70	3	252·660	1855·83	Ditto.
11.	b.	Ditto . .	7·008	0·79725	23	5	87	37	70	58	232·124	1913·90	Mädler.
11.	c.	Ditto . .	6·300	0·24050	11	24	356	22	43	14	632·270	1699·26	Hind.
12.	a.	σ Coronæ B. .	3·918	0·69978	25	7	64	38	29	29	608·450	1826·60	Mädler.
12.	b.	Ditto . .	5·194	0·72560	21	3	69	24	25	39	736·880	1826·48	Hind.
13.		μ 2 Bootis .	3·218	0·84010	117	21	103	17	46	57	649·720	1852·50	Ditto.
14.		α Centauri .	15·500	0·95000	86	7	291	22	47	56	77·000	1851·50	Jacob.

The elements Nos. 1, 2, 3, 4 c, 5, 6 c, 7, 11 b, 12 a, are extracted from M. Mädler's synoptic view of the history of double stars, in vol. ix. of the Dorpat Observations: 4 a, from the Connoiss. des Temps, 1830: 4 b, 6 b, and 11 a, from vol. v. Trans. Astron. Soc. Lond.: 6 a, from Berlin Ephemeris, 1832: No. 8. from Trans. Astron. Soc. vol. vi.: No. 9, 11 c, 12 b, and 13 from Notices of the Astronomical Society, vol. vii. p. 22., and viii. p. 159., and No. 10 from Sir John Herschel's "Results of Astronomical Observations, &c., at the Cape of Good Hope," p. 297. The Σ prefixed to No. 7 denotes the number of the star in M. Struve's Dorpat Catalogue (Catalogus Novus Stellarum Duplicium, &c., Dorpat. 1827), which contains the places for 1826 of 3112 of these objects.

The "position of the node" in col. 4, expresses the angle of position of the line of intersection of the plane of the orbit, with the plane of the heavens on which it is seen projected. The "inclination" in col. 6, is the inclination of these two planes to one another. Col. 5, shows the angle actually included *in the plane of the orbit*, between the line of nodes (defined as above) and the line of apsides. The elements assigned in this table to ω Leonis, ξ Bootis, and Castor must be considered as very doubtful, and the same may perhaps be said of those ascribed to μ 2 Bootis, which rest on too small an arc of the orbit, and that too imperfectly observed, to afford a secure basis of calculation.

62. The most remarkable of these, according to Sir John Herschel, is γ *Virginis;* not only on account of the length of its period, but by reason also of the great diminution of apparent distance and rapid increase of angular motion about each other, of the individuals composing it. It is a bright star of the fourth magnitude, and its component stars are almost exactly equal. It has been known to consist of two stars since the beginning of the eighteenth century, their distance being then between six and seven seconds; so that any tolerably good telescope would resolve it. Since that time they have been constantly approaching, and are at present hardly more than a single second asunder; so that no telescope that is not of very superior quality, is competent to show them otherwise than as a single star somewhat lengthened in one direction. It fortunately happens that Bradley, in 1718, noticed and recorded, in the margin of one of his observation-books, the apparent direction of their line of junction as being parallel to that of two remarkable stars α and δ of the same constellation, as seen by the naked eye. They are entered also as distinct stars in Mayer's catalogue; and this affords also another means of recovering their relative situation at the date of his observations, which were made about the year 1756. Without particularising individual measurements, which will be found in their proper repositories, it will suffice to remark, that their whole series is represented by an ellipse.

63. To understand the curious effects which must attend the case of a lesser sun with its attendant planets revolving round a

greater, let the larger sun with its planets be represented at S, fig. 7, in the focus of an ellipse, in which the lesser sun accompanied by *its* planets moves. At A this latter sun is in its perihelion, and nearest to the greater sun S. Moving in its periodical course to B, it is at its mean distance from the sun S. At D it is at aphelion, or its most distant point, and finally returns through C to its perihelion A. The sun S, because of its vast distance from the system A, would appear to the inhabitants of the planets of the system A much smaller than their proper sun; but, on the other hand, this effect of distance would be to a certain extent compensated by its greatly superior magnitude; for analogy justifies the inference that the sun S is greater than the sun A in a proportion equal to that of the magnitude of our sun to one of the planets. The inhabitants of the planets of the system A will then behold the spectacle of *two suns* in their firmament. The annual motion of one of these suns will be determined by the motion of the planet itself in its orbit, but that of the other and more distant sun will be determined by the period of the lesser sun around the greater in the orbit A B D C. The rotation of the planets on their axes will produce two days of equal length, but not commencing or ending simultaneously. There will be in general *two sunrises* and *two sunsets!* When a planet is situate in the part of its orbit between the two suns, there will be no night. The two suns will then be placed exactly as our sun and moon are placed when the moon is full. When the one sun sets, the other will rise; and when the one rises the other will set. There will be, therefore, continual day. On the other hand, when a planet is at such a part of its orbit that both suns lie in nearly the same direction as seen from it, both suns will rise and both will set together. There

Fig. 7.

will then be the ordinary alternation of day and night as on the earth, but the day will have more than the usual splendour, being enlightened by two suns.

In all intermediate seasons the two suns will rise and set at different times. During a part of the day both will be seen at once in the heavens, occupying different places, and reaching the meridian at different times. There will be *two noons.* In the morning for some time, more or less, according to the season of the year, one sun only will be apparent, and in like manner, in the evening, the sun which first rose will be the first to set, leaving the dominion of the heavens to its splendid companion.

The diurnal and annual phenomena incidental to the planets attending the central sun s will not be materially different, except that to them the two suns will have extremely different magnitudes, and will afford proportionally different degrees of light. The lesser sun will appear much smaller, both on account of its really inferior magnitude and its vastly greater distance. The two days, therefore, when they occur, will be of very different splendour, one being probably as much brighter than the other as the light of noonday is to that of full moonlight, or to that of the morning or evening twilight.

But these singular vicissitudes of light will become still more striking, when the two suns diffuse light of different colours. Let us examine the very common case of the combination of a *crimson* with a *blue* sun. In general, they will rise at different times. When the blue rises, it will for a time preside alone in the heavens, diffusing a blue morning. Its crimson companion, however, soon appearing, the lights of both being blended, a white day will follow. As evening approaches, and the two orbs descend toward the western horizon, the blue sun will first set, leaving the crimson one alone in the heavens. Thus a ruddy evening closes this curious succession of varying lights. As the year rolls on, these changes will be varied in every conceivable manner. At those seasons when the suns are on opposite sides of a planet, crimson and blue days will alternate, without any intervening night; and at the intermediate epochs all the various intervals of rising and setting of the two suns will be exhibited.

PROPER MOTION OF THE STARS.

In common parlance the stars are said to be *fixed.* They have received this epithet to distinguish them from the planets, the sun, and the moon, all of which constantly undergo changes of apparent position on the surface of the heavens. The stars, on the contrary, so far as the powers of the eye unaided by art can discover, never change their relative position in the firmament,

which seems to be carried round us by the diurnal motion of the sphere, just as if the stars were attached to it, and merely shared in its apparent motion.

But the stars, though subject to no motion perceptible to the naked eye, are not absolutely fixed. When the place of a star on the heavens is exactly observed by means of good astronomical instruments, it is found to be subject to a change from month to month and from year to year, small indeed, but still easily observed and certainly ascertained.

64. It has been demonstrated by Laplace, that a system of bodies, such as the solar system, placed in space and submitted to no other continued force except the reciprocal attractions of the bodies which compose it, must either have its common centre of gravity stationary or in a state of uniform rectilinear motion.

The chances against the conditions which would render the sun stationary, compared with those which would give it a motion in *some* direction with *some* velocity, are so numerous that we may pronounce it to be morally certain that our system is in motion in some determinate direction through the universe. Now, if we suppose the sun attended by the planets to be thus moved through space in any direction, an observer placed on the earth would see the effects of such a motion, as a spectator in a steam-boat moving on a river would perceive his progressive motion on the stream by an apparent motion of the banks in a contrary direction. The observer on the earth would, therefore, detect such a motion of the solar system through space by the apparent motion in the contrary direction with which the stars would be affected.

65. Such a motion of the solar system would affect different stars differently. All would, it is true, appear to be affected by a contrary motion, but all would not be equally affected. The nearest would appear to have the most perceptible motion, the more remote would be affected in a less degree, and some might, from their extreme distance, be so slightly affected as not to exhibit any apparent change of place, even when examined with the most delicate instruments. To whatever degree each star might be affected, all the changes of position would, however, apparently take place in the same direction.

The apparent effects would also be exhibited in another manner. The stars in that region of the universe toward which the motion of the system is directed, would appear to recede from each other. The spaces which separate them would seem to be gradually augmented, while, on the contrary, the stars in the opposite quarter would seem to be crowded more closely together, the distances between star and star being gradually diminished. This will be more clearly comprehended by fig. 8.

Let the line S S′ represent the direction of the motion of the system, and let S and S′ represent its positions at any two epochs. At S, the stars A B C would be separated by intervals measured

Fig. 8.

by the angles A S B, and B S C, while at S′ they would appear separated by the lesser angles A S′ B, and B S′ C. Seen from S′, the stars A B C would seem to be closer together than they were when seen from S. For like reasons, the stars *a b c*, towards which the system is here supposed to move, would seem to be closer together when seen from S, than when seen from S′. Thus, in the quarter of the heavens towards which the system is moving, the stars might be expected to separate gradually, while in the opposite quarter they would become more condensed. In all the intermediate parts of the heavens they would be affected by a motion contrary to that of the solar system. Such, in general, would be the effects of a progressive motion of our system.

66. Although no general effect of this kind has been manifested in any conspicuous manner among the fixed stars, many of these objects have been found, in long periods of time, to have shifted their position in a very sensible degree. Thus, for example, the three stars, Sirius, Arcturus, and Aldebaran, have undergone, since the time of Hipparchus (130 B.C), a change of position southwards, amounting to considerably more than half a degree. The double star 61 Cygni has, in half a century, moved through nearly 4·3′, the two stars composing it being carried along in parallel lines with a common velocity. The stars ϵ Indi and μ Cassiopeiæ move at the rate of 7·74″ and 3·74″ annually.

Various attempts have been made to render these and other like changes of apparent position of the fixed stars compatible with some assumed motion of the sun. Sir W. Herschel, in 1783, reasoning upon the proper motions which had then been observed, arrived at the conclusion, that such appearances might be explained by supposing that the sun has a motion directed to a point near the star λ Herculis. About the same time, Prevost came to a like conclusion, assigning, however, the direction of the supposed motion to a point differing by 27° from that indicated by Sir W. Herschel.

Since that epoch, the proper motions of the stars have been

8

more extensively and accurately observed, and calculations of the motions of the sun which they indicate, have been made by several astronomers. The following points have been assigned as the direction of the solar motion in 1790:—

R. A.		N. P. D.		
260° 34′	... ...	63° 43′	... ...	Sir W. Herschel.
256° 25′	... ...	51° 23′	... ...	Argelander.
255° 10′	... ...	51° 26′	... ...	,,
261° 11′	... ...	59° 2′	... ...	,,
252° 53′	... ...	75° 34′	... ...	Luhndahl.
261° 22′	... ...	62° 24′	... ...	Otto Struve.

The first estimate of Argelander was made from the proper motions of 21 stars, each of which has an annual motion greater than 1″; the second from 50 stars having annual proper motions between 1″ and 0·5″, and the third from those of 319 stars having motions between 0·5″ and 0·1″. The estimate of M. Luhndahl is based on the motions of 147 stars, and that of M. Struve on 392 stars.

The mean of all these estimates * is a point whose right ascension is 259° 9′, and north polar distance 55° 23′, which it will be seen differs very little from the point originally assigned by Sir W. Herschel.

All the preceding calculations being based on observations made on stars in the northern hemisphere, it was obviously desirable that similar estimates should be made from the observed proper motions of southern stars. Mr. Galloway undertook and executed these calculations; and found that the southern stars gave the direction of the solar motion for 1790, to be towards a point whose right ascension is 260° 1′, and north polar distance 55° 37′.

No doubt, therefore, can remain that the proper motion of the stars is produced by a real motion of the solar system, and that the direction of this motion in 1790 was towards a point of space which seen from the then position of the system had the right ascension of about 260°, and the north polar distance of about 55°.

67. It follows from these calculations, that the average displacement of the stars requires that the motion of the sun should be such as that if its direction were at right angles to a visual ray, drawn from a star of the first magnitude of average distance, its apparent annual motion would be 0·3392″; and taking the average parallax of such a star at 0·209″, if D express the semi-axis of the earth's orbit, the annual motion of the sun would be

$$\frac{3392}{2090} \times D = 1{\cdot}623\ D.$$

* Herschel, Ast., 2nd Ed., p. 583.

It follows therefore, that the annual motion of the sun would be

$$1{\cdot}623 \times 95{,}000000 = 154{,}200000 \text{ miles};$$

and the daily motion

$$\frac{154{,}200000}{365\frac{1}{4}} = 422000 \text{ miles};$$

a velocity equal to something more than the fourth of the earth's orbital motion.

68. The motion of the sun, which has been computed in what precedes, is that which it had at a particular epoch. No account is taken of the possible or probable changes of direction of such motion. To suppose that the solar system should move continuously in one and the same direction, would be equivalent to the supposition that no body or collection of bodies in the universe would exercise any attraction upon it. It is obviously more consistent with probability and analogy, that the motion of the system is *orbital*, that is to say, that it revolves round some remote centre of attraction, and that the direction of its motion must continually change, although such change, owing to the great magnitude of its orbit, and the relative slowness of its motion, be so very slow as to be quite imperceptible within even the longest interval over which astronomical records extend.

Attempts have, nevertheless, been made to determine the centre of the solar motion; and Dr. Mädler has thrown out a surmise that it lies at a point in or near the small constellation of the Pleiades.

This and like speculations must, however, be regarded as conjectural for the present.

THE FORM AND DIMENSIONS OF THE MASS OF STARS WHICH COMPOSE THE VISIBLE FIRMAMENT.

69. The aspect of the firmament might, at first, impress the mind of an observer with the idea that the numerous stars scattered over it are destitute of any law or regularity of arrangement, and that their distribution is like the fortuitous position which objects casually flung upon such a surface might be imagined to assume. If, however, the different regions of the heavens be more carefully examined and compared, this first impression will be corrected, and it will, on the contrary, be found that the distribution of the stars over the surface of the celestial sphere follows a distinct and well defined law; that their density, or the number of them which is found in a given space of the heavens, varies regularly, increasing continually in certain directions and decreasing in others.

Sir W. Herschel submitted the heavens, or at least that part

of them which is observable in these latitudes, to a rigorous telescopic survey, counting the number of individual stars visible in the field of view of a telescope of given aperture, focal length, and magnifying power, when directed to different parts of the firmament. The result of this survey proved that, around two points of the celestial sphere diametrically opposed to each other, the stars are more thinly scattered than elsewhere; that departing from these points in any direction, the number of stars included in the field of view of the same telescope increases first slowly, but at greater distances more rapidly; that this increase continues until the telescope receives a direction at right angles to the diameter which joins the two opposite points where the distribution is most sparse; and that in this direction the stars are so closely crowded together that it becomes, in some cases, impracticable to count them.

70. The two opposite points of the celestial sphere, around which the stars are observed to be most sparse, have been called the GALACTIC POLES; and the great circle at right angles to the diameter joining these points, has been denominated the GALACTIC CIRCLE.

This circle intersects the celestial equator at two points, situate 10° east of the equinoctial points, and is inclined to the equator at an angle of 63°, and, therefore, to the ecliptic at an angle of 40°.

In referring to and explaining the distribution of the stars over the celestial sphere, it will be convenient to refer them to this circle and its poles, as, for other purposes, they have been referred to the equator and its poles. We shall, therefore, express the distance of different points of the firmament from the galactic circle, in either hemisphere, by the terms north or south GALACTIC LATITUDE.

71. The elaborate series of stellar observations in the northern hemisphere made during a great part of his life, by Sir W. Herschel, and subsequently extended and continued in the southern hemisphere by Sir J. Herschel, has supplied data by which the law of the distribution of the stars, according to their galactic latitude, has been ascertained at least with a near approximation.

The great celestial survey executed by these eminent observers, was conducted upon the principle explained above. The telescope used for the purpose had 18 inches aperture, 20 feet focal length, and a magnifying power of 180. It was directed indiscriminately to every point of the celestial sphere visible in the latitude of the places of observation.

It was by means of a vast number of distinct observations thus made, that the position of the galactic poles was ascertained. The density of the stars, measured by the number included in each "gauge" (as the field of view was called), was nearly the same for the same galactic latitude, and increased in proceeding

from the galactic pole, very slowly at first, but with great rapidity when the galactic latitude was much diminished.

72. An analysis of the observations of Sir W. Herschel, in the northern hemisphere, was made by Professor Struve, with the view of determining the mean density of the stars in successive zones of galactic latitude; and a like analysis has been made of the observations of Sir J. Herschel, in the southern hemisphere.

If we imagine the celestial sphere resolved into a succession of zones, each measuring 15° in breadth, and bounded by parallels to the galactic circle, the average number of stars included within a circle, whose diameter is 15′, and whose magnitude, therefore, would be about the fourth part of that of the disc of the sun or moon, will be that which is given in the second column of the following Table.

Galactic Latitude.	Average number of Stars in a circle 15′ diameter.
N 90° — 75°	4·32
,, 75° — 60°	5·42
,, 60° — 45°	8·21
,, 45° — 30°	13·61
,, 30° — 15°	24·09
,, 15° — 0°	53·43
S 0° — 15°	52·06
,, 15° — 30°	26·29
,, 30° — 45°	13·49
,, 45° — 60°	9·08
,, 60° — 75°	6·62
,, 75° — 90°	6·05

It appears, therefore, that the variation of the density of the visible stars in proceeding from the galactic plane, either north or south, is subject almost exactly to the same law of decrease, the density, however, at each latitude being somewhat greater in the southern than in the northern hemisphere.

73. The regions of the heavens, which extend to a certain distance on one side and the other of the galactic plane, are generally so densely covered with small stars, as to present to the naked eye the appearance, not of stars crowded together, but of whitish nebulous light. This appearance extends over a vast extent of the celestial sphere, deviating in some places from the exact direction of the galactic circle, bifurcating and diverging into two branches at a certain point which afterwards reunite, and at other places throwing out off-shoots. This appearance was denominated the *Via Lactea*, or the *galaxy*,* by the ancients, and it has retained that name.

The course of the milky way may be so much more easily and clearly

* From the Greek word γάλα, γάλακτος, "milk."

followed by means of a map of the stars, or a celestial globe, upon which it is delineated, that it will be needless here to describe it.

74. When this nebulous whiteness is submitted to telescopic examination with instruments of adequate power, it proves to be a mass of countless numbers of stars, so small as to be individually undistinguishable, and so crowded together as to give to the place they occupy the whitish appearance from which the milky way takes its name.

Some idea may be formed of the enormous number of stars which are crowded together in those parts of the heavens, by the actual numbers so distinctly visible as to admit of being counted or estimated, which are stated by Sir W. Herschel to have been seen in spaces of given extent. He states, for example, that in those parts of the milky way in which the stars were most thinly scattered, he sometimes saw eighty stars in each field. In an hour, fifteen degrees of the firmament were carried before his telescope, showing successively sixty distinct fields. Allowing eighty stars for each of these fields, there were thus exhibited, in a single hour, without moving the telescope, four thousand eight hundred distinct stars! But by moving the instrument at the same time in the vertical direction, he found that in a space of the firmament, not more than fifteen degrees long, by four broad, he saw fifty thousand stars, large enough to be individually visible and distinctly counted! The surprising character of this result will be more adequately appreciated, if it is remembered that this number of stars thus seen in the space of the heavens, not more than thirty diameters of the moon's disc in length, and eight in breadth, is fifty times greater than all the stars taken together, which the naked eye can perceive at any one time in the heavens, on the most serene and unclouded night!

On presenting the telescope to the richer portion of the *via lactea*, Herschel found, as might be expected, much greater numbers of stars. In a single field he was able to count 588 stars; and for fifteen minutes, the firmament being moved before his telescope by the diurnal motion, no diminution of number was apparent; the number seen at any one time being greater than can be seen by the naked eye, on the entire firmament, except on the clearest nights.

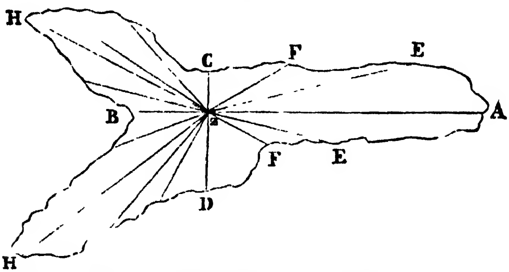
75. It may be considered as established by a body of analogical evidence, having all the force of demonstration, that the fixed stars are self-luminous bodies, similar to our sun; and that although they may differ more or less from our sun and from each other in magnitude and intrinsic lustre, they have a certain average magnitude; and that, therefore, in the main, the great

13

differences which are apparent in their brightness, is to be ascribed to difference of distance. Assuming, then, that they are separated from each other by distances analogous to their distances from the sun, itself a star, the general phenomena which have been described above, involving the rapid increase of stellar density in approaching the galactic plane, combined with the observed form of the milky way, which, following the galactic plane in its general course, departs nevertheless from it at some points, bifurcates resolving itself into two diverging branches at others, and at others throws out irregular off-shoots, conducted Sir W. Herschel to the conclusion, that the stars of our firmament, including those which the telescope renders visible, as well as those visible to the naked eye, instead of being scattered indifferently in all directions around the solar system through the depths of the universe, form a stratum of definite form and dimensions, of which the thickness bears a very small proportion to the length and breadth, and that the sun and solar system is placed within this stratum, very near its point of bifurcation, relatively to its breadth near its middle point, and relatively to its thickness (as would appear from the more recent observations) nearer to its northern than to its southern surface.

Let A C H D, fig. 9, represent a rough outline of a section of such a stratum, made by a plane passing through or near its centre.

Fig. 9.



Let A B represent the intersection of this with the plane of the galactic circle, so that, z being the place of the solar system, z C will be the direction of the north, and z D that of the south galactic pole. Let z H represent the two branches which bifurcate from the chief stratum at B. Now, if we imagine visual lines to be drawn from z in all directions, it will be apparent that those z C and z D, which are directed to the galactic poles, pass through a thinner bed of stars than any of the others; and since z is supposed to be nearer to the northern than to the southern side of the stratum, z C will pass through a less thickness of stars than

z D. As the visual lines are inclined at greater and greater angles to z A, their length rapidly decreases, as is evident by comparing z A, z E, and z F, which explains the fact that while the stars are as thick as powder in the direction z A, they become less so in the direction z E, and still less in the direction z F, until at the poles in the directions z C and z D, they become least dense.

On the other side, z B being less than z A, a part of the galactic circle is found at which the stars are more thinly scattered; but in two directions, z H intermediate between z B and the galactic poles, they again become nearly as dense as in the direction z A.

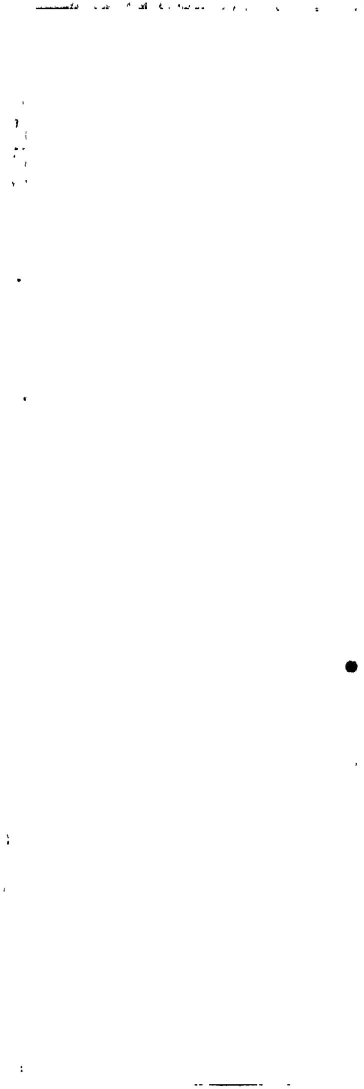
This illustration must, however, be taken in a very general sense. No attempt is made to represent the various off-shoots and variations of length, breadth, and depth of the stratum measured from the position of the solar system within it, which have been indicated by the telescopic *soundings* of Sir W. Herschel and his illustrious son, whose wondrous labours have effected what promises in time, by the persevering researches of their successors, to become a complete analysis of this most marvellous mass of systems. Meanwhile it may be considered as demonstrated, that it consists of myriads of stars clustered together:—

> "A broad and ample road, whose dust is gold,
> And pavement stars, as stars to us appear;
> Seen in the galaxy that Milky Way,
> Like to a circling zone powder'd with stars."—MILTON.

The appearance which this mass of stars would present if viewed from a position directly above its general plane, and at a sufficient distance to allow its entire outline to be discerned, was represented by Sir William Herschel as resembling the starry stratum sketched in fig. 10.

He considered that it was probable that the *thickness* of this *bed of stars* was equal to about eighty times the distance of the nearest of the fixed stars from our system; and supposing our sun to be near the middle of this thickness, it would follow that the stars on its surface in a direction perpendicular to its general plane would be at the fortieth order of distance from us. The stars placed in the more remote edges of its *length* and *breadth* he estimated to be in some places at the nine-hundredth order of distance from us, so that its extreme length may be said to be in round numbers about 2000 times the distance of the nearest fixed stars from our system. Such a space light would take 20000 years to move over, moving all that time at the rate of nearly 200000 miles between every two ticks of a common clock!

Fig. 10.



Figs. 85, 86.—SPIRAL NEBULÆ, AS SHOWN BY THE GREAT ROSSE TELESCOPE.

THE STELLAR UNIVERSE.

CHAPTER V.

STELLAR CLUSTERS AND NEBULÆ: 76. The stars of the firmament a stellar cluster.—77. Such clusters innumerable.—78. Their distribution on the firmament.—79. Their constitution.—80. Their apparent and real forms.—81. Nebulæ.—82. Double nebulæ.—83. Planetary nebulæ.—84. Annular nebulæ.—85. Spiral nebulæ.

STELLAR CLUSTERS AND NEBULÆ.

76. IT appears, then, that our sun is an individual star, forming only a single unit in a cluster or mass of many millions of other similar stars; that this cluster has limited dimensions, has ascertainable length, breadth, and thickness, and, in short, forms what may be expressed by a *universe of solar systems*. The mind, still

unsatisfied, is as urgent as before in its questions regarding the *remainder of immensity*. However vast the dimensions of this mass of suns be, they are nevertheless finite. How stupendous soever be the space included within them, it is still *nothing* compared to the immensity which lies outside! Is that immensity a vast solitude? Are its unexplored realms dark and silent? Has Omnipotence circumscribed its agency, and has Infinite Beneficence left those unfathomed regions destitute of evidence of His power?

That the infinitude of space should exist without a purpose, unoccupied by any works of creation, is plainly incompatible with all our notions of the character and attributes of the Author of the universe, whether derived from the voice of revelation or from the light of nature. We should therefore infer, even in the absence of direct evidence, that *some* works of creation are dispersed through those spaces which lie beyond the limits of that vast stellar cluster of which our system is a part. Nay, we should be led, by the most obvious analogies, to conjecture that *other stellar clusters*, like our own, are dispersed through immensity, separated probably by distances as much greater than those which intervene between star and star, as the latter are greater than those which separate the bodies of the solar system. But if such distant clusters existed, it may be objected, that they must be visible to us; that although diminished, perhaps, to mere spots on the firmament, they would still be rendered apparent, were it only as confused whitish patches, by the telescope; that as the stars of the milky way assume to the naked eye the appearance of mere whitish nebulosity, so the far more distant stars of other clusters, which cannot be perceived at all by the naked eye, would, to telescopes of adequate power, present the same whitish nebulous appearance; and that we might look forward without despair to such augmentation of the powers of the telescope as may even enable us to perceive them to be actual clusters of stars.

77. Such anticipations have accordingly been realised. In various parts of the firmament objects are seen which, to the naked eye, appear like stars seen through a mist, and sometimes as nebulous specks, which might be, and not infrequently have been, mistaken for comets. With ordinary telescopes these objects are visible in very considerable numbers, and were observed nearly a century ago. In the *Connaissance des Temps*, for 1784, Messier, then so celebrated for his observations on comets, published a catalogue of 103 objects of this class, of many of which he gave drawings, with which all observers who search for comets ought to be familiar, to avoid being misled by their resemblance to them. The improved powers of the telescope speedily disclosed to astro-

nomers the nature of these objects, which, when examined by sufficient magnifying powers, prove to be masses of stars clustered together in a manner identical with that cluster in which our sun is placed. They appear as they do, mere specks of whitish light, because of their enormous distance.

78. These objects are not dispersed fortuitously and indifferently on all parts of the heavens. They are wholly absent from some regions, in some rarely found, and crowded in amazing profusion in others. Their disposition, however, is not like that of the stars in general, determined by a great circle of the sphere and its poles. It was supposed that they showed a tendency to crowd towards a zone at right angles to the galactic circle, but a careful comparison of their position does not confirm this. According to Sir W. and Sir J. Herschel, the nebulæ prevail most around the following parts of the celestial sphere :—

1 The North Galactic Pole.	5 Canes Venatici.
2 Leo major.	6 Coma Berenici.
3 Leo minor.	7 Bootes (precedingly).
4 Ursa major.	8 Virgo (head, wings, and shoulder).

The parts of the heavens, on the other hand, where they are found in the smallest numbers, are,—

1 Aries.	7 Draco.
2 Taurus.	8 Hercules.
3 Orion (head and shoulders).	9 Serpentarius (northern part).
4 Auriga.	10 Serpens (tail).
5 Perseus.	11 Aquila (tail).
6 Camelopardus.	12 Lyra.

In the southern hemisphere their distribution is more uniform.

79. What those objects are, and of what they severally consist, admits of no reasonable doubt. So far as relates to the stellar clusters, their constituent parts are visible. They are, as their name imports, masses of stars collected together at certain points in the regions of space which stretch beyond the limits of our own cluster, and are by distance so reduced in their visual magnitude, that an entire cluster will appear to the naked eye, if it be visible at all, as a single star, and when seen with the telescope will be included within the limit of a single field of view.

Different clusters exhibit their component stars seen with the same magnifying power more or less distinctly. Thus, for example, fig. 11 represents the appearance of a cluster seen with a powerful telescope, in which the stars appear like grains of silver powder.

In fig. 12, on the other hand, the component stars are distinct, and those of fig. 13 still more so.

This may be explained either by difference of distance, or by the supposition that they may consist of stars of different real magnitudes, and crowded more or less closely together. The former supposition is, however, by far the more natural and probable.

The appearance of the stars composing some of the clusters is quite gorgeous. Sir J. Herschel says, that the cluster which surrounds κ Crucis in the southern hemisphere, occupies the 48th part of a square degree, or about the tenth part of the superficial magnitude of the moon's disc, and consists of about 110 stars from the 7th magnitude downwards, eight of the more con-

Fig. 11.

Fig. 12.

spicuous stars being coloured with various tints of red, green, and blue, so as to give to the whole the appearance of a rich piece of jewellery.

Fig. 13.

Cluster compared with cluster show all gradations of smallness and closeness of the component stars, until they assume the appearance of patches of starry powder. These varieties are more obviously ascribable to varying distances.

Then follow those patches of starry light which are seen in so many regions of the heavens, and which have been denominated nebulæ, appearing with very different degrees of magnitude and brightness. Telescopic views of three such are given in figs. 14, 15, and 16.

That these are still clusters, of which the component stars are indistinguishable by reason of their remoteness, there are the

Fig. 15.

Fig. 14.

strongest evidence and most striking analogies to prove. Every augmentation of power and improvement of efficiency the telescope receives, augments the number of nebulæ which are converted by that instrument into clusters. Nebulæ which were irresolvable before the time of Sir W. Herschel, yielded in large numbers to the powers of the instruments which that observer brought to bear upon them. The labours of Sir J. Herschel, the colossal telescopes constructed by Lord Rosse, and the erection of observatories in multiplied numbers in climates and under skies more favourable to observation, have all tended to augment the number of nebulæ which have been resolved, and it may be expected that this progress will continue, the resolution of these objects into stellar clusters being co-extensive with the improved powers of the telescope and the increased number and zeal of observers.

Fig. 16.

A theory was put forward to explain these objects, based upon views not in accordance with what has just been related. It was assumed hypothetically that the nebulous matter was a sort of luminous fluid diffused through different parts of the universe; that by its aggregation on certain laws of attraction, solid luminous masses in process of time were produced, and that these nebulæ grew into clusters.

It would not be compatible with the limits of this Tract, and the objects to which it is directed, to pursue this speculation

through its consequences, to state the arguments by which it is supported and opposed; and it is the less necessary to do so, seeing that such an hypothesis is not needed to explain appearances which are so much more obviously and simply explicable by the admission of a gradation of distances.

80. The apparent forms of these objects are extremely various, and subject to most extraordinary and unexpected changes, according to the magnifying power under which they are viewed. This ought, however, to excite no surprise. The telescope is an expedient by which a well-defined and strongly illuminated optical image of a distant object is formed so close to the observer, that he is enabled to view it with microscopes of greater or less power, according to the perfection of its definition, and the intensity of its illumination. Now, it is known to all who are familiar with the use of the microscope, that the apparent form and structure of an object change in the most remarkable and unexpected way when viewed with different microscopic powers. The blood, for example, which viewed with the naked eye, or with low powers, is a uniformly red fluid, appears as a pellucid liquid, having small red discs floating in it, when seen with higher powers. Like effects are manifested in the cases of the nebulæ, when submitted to examination with different and increasing magnifying powers, of which we shall presently show many striking examples.

Stellar clusters are generally roundish or irregular patches. The stars which compose them are always much more densely crowded together, in going from the edges of the cluster towards the centre, so that at the centre they exhibit a perfect blaze of light.

The apparent form is that of a section of the real form, made by a plane at right angles to the visual ray. If the mass had a motion of rotation, or any other motion by which it would change this plane, so as to exhibit to the eye successively different sections of it, its real form could be inferred as those of the planets have been. But there are no discoverable indications of any such motion in these objects. Their real forms, therefore, can only be conjectured from comparing their apparent forms with their structural appearance.

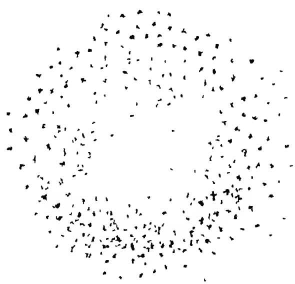
The clusters having round apparent forms, and of which the stars are rapidly more dense towards the centres, are inferred to be either globular or spheroidal masses of stars, the greater apparent density in passing from the edges to the centre being explained by the greater thickness of the mass, in the direction of the visual line. Clusters of irregular outline which show also a density increasing inwards, are also inferred, for like reasons, to be masses of stars, whose dimensions in the direction of the visual

rays correspond with their dimensions in the direction at right angles to those rays.

In fig. 17 is represented a cluster observed and delineated by Sir J. Herschel. It is situated at about $1\frac{1}{2}°$ south of the celestial equator, and about $38\frac{1}{2}°$ east of the autumnal equinoctial point. It occupies a space on the heavens, the diameter of which is equal to the 300th part of that of the full moon. Sir John Herschel, who observed it with a reflecting telescope of nine inch aperture, describes its appearance as that of a most superb cluster of stars of the fifteenth magnitude, so condensed towards the centre as to become a perfect blaze of light. He compares it to a mass of fine luminous sand.

Nothing can be more striking than the different appearances which the same objects have presented, when viewed by the

Fig. 17.



telescopes of Sir John Herschel and the more powerful instruments constructed by the Earl of Rosse. In fig. 18 we have given the same cluster as it appears in one of Lord Rosse's telescopes.

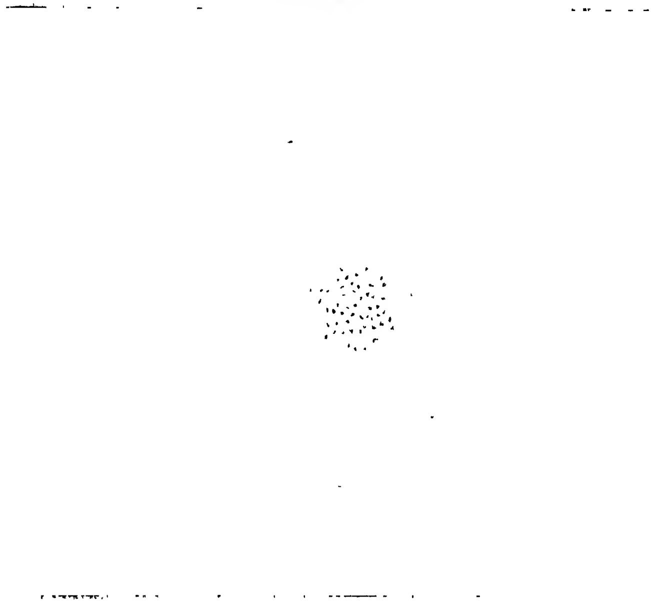
The stars which, in Sir John Herschel's instruments, are crowded together so as to produce a blaze of light, are completely separated by the telescope of Lord Rosse.

In fig. 19 is represented an object as delineated by Sir John Herschel, which appears in his telescope as a fine oval nebula, the length of which is about the eighth, and the breadth the tenth, part of the moon's diameter. This nebula is situated a few

degrees north of the constellation of Orion, between it and Aldebaran.

In fig. 20, the same object is delineated as shown by Lord Rosse's telescope. Here a still greater change of appearance is produced than in the former case. The oval form is lost, and converted into that which is shown in the figure. The object is studded with innumerable stars, which are projected upon a nebulous ground. This nebulous ground would most evidently be resolved into stars if viewed with still higher powers.

Fig. 18.



81. The nebulæ, properly so called, present a much greater variety of form than the stellar clusters. Some are circular, with more or less precision of outline. Some are elliptical, the oval outline having degrees of excentricity infinitely various, from one which scarcely differs from a circle, to one which is compressed into a form not sensibly different from a straight line. In short, the minor axis of the ellipses bears all proportions to the major axis, until it becomes a very small fraction of the latter.

To infer the real from the apparent forms of these objects with any certainty, there are no sufficient data. But in the cases in

which the brightness increases rapidly towards the centre, which it very generally does, it may be probably conjectured that their forms are globular or spheroidal, for the reasons already explained

Fig. 19.

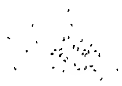


Fig. 20.

in relation to the clusters, and this becomes the more probable when it is considered, that these nebulæ are in fact clusters, the stars of which are reduced to a nebulous patch by distance.

Nevertheless, these nebulæ may be strata of stars, of which the thickness is small compared with their other dimensions; and supposing their real outline to be circular, they will appear elliptical if the plane of the stratum be inclined to the visual line, and more or less excentrically elliptical, according as the angle of inclination is more or less acute. In cases in which the brightness does not increase in a striking degree from the edges inwards, this form is more probable than the globular or the spheroidal.

Nebulæ may be conveniently classed according to their apparent form and structure; but whatever arrangement may be adopted, these objects exhibit such varieties, assume such capricious and irregular forms, and undergo such strange and unexpected changes of appearance according to the increasing power of the telescope with which they are viewed, that it will always be found that great numbers of them will remain unavoidably unclassified.

82. Like individual stars, nebulæ are found to be combined in pairs too frequently to be compatible with the supposition, that such combinations arise from the fortuitous results of the small obliquity of the visual rays, which causes mere optical juxtaposition.

In figs. 21, 22, 23, and 24, four double nebulæ of this class are represented.

In fig. 21, the visual line passes between them without touching

Fig. 21.

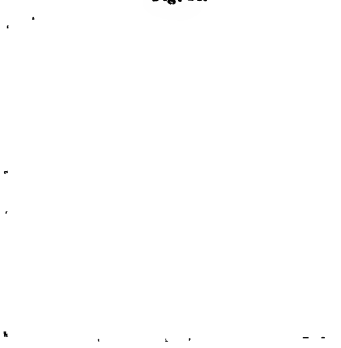


Fig. 22.

either, and they are consequently seen completely separated. They are in this case equal in magnitude.

In fig. 22 they are also equal in magnitude, but the distance between their centres being less than their diameter, they partially overlay each other.

In figs. 23 and 24 they are unequal, and also partly overlay each other.

Fig. 23. Fig. 24.

These double nebulæ are generally circular in their apparent, and therefore probably globular in their real form. In some cases they are resolvable clusters.

That such pairs of clusters are physically connected does not admit of a reasonable doubt, and it is highly probable that, like the binary stars, they move round each other, or round a common centre of attraction, although the apparent motion attending such revolution is rendered so slow by their immense distance that it can only be ascertained after the lapse of ages.

83. *Planetary Nebulæ.*—This class of objects derive their name from their close resemblance to planetary discs. They are in general either circular or very slightly oval. In some cases the disc is sharply defined, in others it is hazy and nebulous at the edges. In some the disc shows a uniform surface, and in some it has an appearance which Sir J. Herschel describes by the term *curdled.*

There is no reason to doubt that the constitution of these objects is the same as that of other nebulæ, and that they are in fact clusters of stars which by mutual proximity and vast distance are reduced to the form of planetary discs.

Nebulæ of this class, which are not numerous, present some remarkable peculiarities of appearance and colour. It has been already observed that, although the companion of a red individual of a double star appears blue or green, it is not certain that this is its real colour, the optical effect of the strong red of its near neighbour being such as would render a white star apparently blue or green, and no example of any single blue or green star

has ever been witnessed. The planetary nebulæ, however, present some very remarkable examples of these colours. Sir J. Herschel indicates a beautiful instance of this, in a planetary nebula situate in the southern constellation of the Cross. The apparent diameter is 12″, and the disc is nearly circular, with a well-defined outline, and a "fine and full blue colour verging somewhat upon green." Several other planetary nebulæ are of a like colour, but more faint.

The magnitudes of these stupendous masses of stars may be conjectured from their probable distances. One of the largest, and therefore probably the nearest of them, is situate near the star β Ursæ majoris (one of the pointers). Its apparent diameter is 2′ 40″. Now, if this were only at the distance of 61 Cygni, whose parallax is known, it would have a diameter equal to seven times that of the extreme limit of the solar system; but as it is certain that its distance must be many times greater, it may be conceived that its dimensions must be enormous.

In fig. 25 is represented a small nebula of this class, drawn by Sir J. Herschel. It is situate near the star δ in the constellation Hercules (R A, 17^h 45^m N P D, 66° 53′), and is described as having a

Fig. 25. Fig. 26.

perceptible disc from 1″ to 1½″ in diameter, surrounded by a faint nebula.

In fig. 26 is another similar object, situated a little to the north of the constellation of Lyra (R A 19^h 40^m N P D 39° 54′). A most curious object. A star of the 11th magnitude, surrounded by a very bright and perfectly round planetary nebula of uniform light. Diameter in R A 3·5″, perhaps a very little hazy at the edges. (Herschel.)

In fig. 27 is represented another of the same class, situated in (R A 13^h 29^m N P D 107° 1′) the constellation Virgo near the bright star *Spica*. Its entire diameter is 2′, being the 15th of that of the moon, and the diameter of the bright central part 10″ to 15″. It is described as a faint large nebula losing itself quite imperceptibly; a good type of its class. (Herschel.)

In fig. 28 is a nebula, situate in (R A 10^h 28^m N P D 35° 36′). It

is described as a bright round nebula, forming almost a disc 15″ diameter, surrounded by a very feeble atmosphere. (Herschel.)

Fig. 27.

Fig. 28.

84. *Annular Nebulæ.*—A very few of the nebulæ have been observed to be annular. Until lately there were only four. The telescopes of Lord Rosse have, however, added five to the number, by showing that certain nebulæ formerly supposed to be small round patches are really annular. It is extremely probable, that many others of the smaller class of round nebulæ will prove to be annular, when submitted to further examination with telescopes of adequate power and efficiency.

In fig. 29 one of this class is given, the situation of which is (R A 8^h 47^m N P D 57° 11′) between the constellations of Gemini and Cancer. This object, drawn by Sir J. Herschel, is the annular nebula between β and γ Lyræ. He estimates its diameter at 6″·5. The annulus is oval, its longer axis being inclined at 57° to the meridian. The central vacuity is *not black*, but filled with a

Fig. 29.

Fig. 30.

nebulous light. The edges are not sharply cut off, but ill defined; they exhibit a curdled and confused appearance, like that of stars out of focus. He considers it not well represented in the drawing.

Fig. 30 is the same object as shown in the telescope of Lord Rosse. This drawing was made with the smaller telescope, three feet aperture, before the great telescope had been erected. The nebula was observed seven times in 1848, and once in 1849. With the large telescope, the central opening showed considerably more nebulosity than it appeared to have with the smaller instrument. It was also noticed, that several small stars were seen around it with the large instrument, which did not appear with the smaller one, from which it was inferred that the stars seen in the dark opening of the ring may possibly be merely accidental, and have no physical relation to the nebula. In the annulus near the extremity of the minor axis, several minute stars were visible.

85. *Spiral Nebulæ.*—The discovery of this class of objects, the most extraordinary and unexpected which modern research has yet disclosed in stellar astronomy, is due to Lord Rosse. Their general form and character may be conceived by referring to those represented in figs. 32 and 34. These extraordinary

Fig. 31.

forms are so entirely removed from all analogy with any of the phenomena presented either in the motions of the solar system, or the comets, or those of any other objects to which observation has been directed, that all conjecture as to the physical condition

of the masses of stars which could assume such forms would be vain. The number of instances as yet detected, in which this form prevails, is not great; but it is sufficient to prove that the phenomenon, whatever be its cause, is the result of the operation of some general law. It is pretty certain, that when the same powerful instruments which have rendered these forms visible in objects which had already been so long under the scrutiny of the most eminent observers of the last hundred years, including Sir W. and Sir J. Herschel, aided by the vast telescopic powers at their disposition, without raising even a suspicion of their real form and structure, have been applied to other nebulæ, other cases of the same phenomenon will be brought to light. In this point of view it is much to be regretted, that the telescopes of Lord Rosse cannot have the great advantage of being used under skies more favourable to stellar researches, since the discovery of such forms as these not only requires instruments of such power as Lord Rosse alone possesses at present, but also the most favourable atmospheric conditions.

In connection with this class of objects, and indeed with the nebulæ generally, one of the most remarkable is situate (R A 13^h 33^m N P D $41° 56'$); as shown in fig. 31, it was observed and drawn by Sir John Herschel. "This is," says that eminent astronomer, "in many respects, one of the most remarkable and interesting of its class, and has been submitted to elaborate examination by all the eminent observers." The distance of the centre of the small nebula from that of the large one, is given by Messier, as $4' 35''$, which may serve as a *modulus* for its other dimensions. It was described by Sir W. Herschel as a bright round nebula, surrounded by a halo or glory, and attended by a companion. Sir J. Herschel observed this object, and represented it as in the figure. He noticed the partial division of the ring, as if it were split, as its most remarkable and interesting feature, and inferred that, supposing it to consist of stars, the appearance it would present to an observer, placed on a planet attached to one of them excentrically situate towards the north preceding quarter of the central mass, would be exactly similar to that of the milky way as seen from the earth, traversing in a manner precisely similar the firmament of large stars, into which the central cluster would be seen projected, and (owing to its greater distance) appearing like it to consist of stars much smaller than those in other parts of the heavens. "Can it be," asks Sir J. Herschel, "that we have here a brother system, bearing a real physical resemblance and strong analogy of structure to our own?" Sir J. Herschel further argues, that all idea of symmetry caused by rotation must be relinquished, considering that the elliptical form of the inner subdivided portion

indicates with extreme probability an elevation of that part above the plane of the rest; so that the real form must be that of a ring split through half its circumference, and having the split portions set asunder at an angle of 45°.

Fig. 32 is the same object as shown by Lord Rosse's telescope. This shows, in a striking manner, how entirely the appearances of these objects are liable to be varied by the increased magnifying power and greater efficiency of the telescope through which they are viewed. It is evident, that very little resemblance or analogy is discoverable between fig. 31 and fig. 32. Lord Rosse, however,

Fig. 32.

says that if Sir John Herschel's be placed as it would be seen with a Newtonian telescope, the bright convolutions of the spiral shown in his own would be recognised in the appearance which Sir J. Herschel supposed to be that which would be produced by a split or divided ring. Lord Rosse further observes that, with each increase of optical power, the structure of this object becomes more complicated and more unlike anything which could be supposed to be the result of any form of dynamical law of which we find a counterpart in our system. The connection of the companion with the principal nebula, of which there is not the least doubt, and which is represented in the sketch, adds, in Lord Rosse's opinion, if possible, to the difficulty of forming any conceivable hypothesis. That such a system should exist without internal movement he considers in the last degree improbable. Our conception may be aided, by uniting with the idea of motion the effects of a resisting medium; but it is impossible to imagine such a system in any point of view, as a case of mere statical equilibrium. Measurements he therefore considers of the highest interest, but of great difficulty.

Fig. 50.

Fig. 51.

THE STELLAR UNIVERSE.

CHAPTER VI.

Spiral nebulæ (continued).—86. Number of nebulæ.—87. The Dumb-Bell nebula as observed by Sir J. Herschel and Lord Rosse.—88. Various nebulæ figured by the same observers.—89. Large irregular nebulæ.—90. Rich cluster in the Centaur.—91. The great nebula in Orion.—92. The great nebula in Argo.—93. Magellanic clouds.

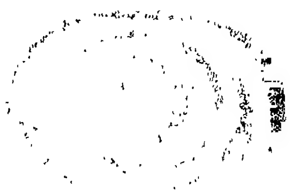
In fig. 33 is reproduced a drawing by Sir J. Herschel of a large nebula having a diameter estimated by him at 3′, or a tenth of that of the moon. This object is situate in R A 9^h 22^m N P D 67° 45′, and therefore near the northern part of the constellation of Leo minor. This is described by Sir John Herschel as a very bright extended nebula, with an approach to a second nucleus, which, however, is very faint.

Fig. 34 is the same object as shown by Lord Rosse's telescope. This object was first observed with the great telescope, 24th March, 1846, when a tendency to an annular or spiral form was discovered. On the 9th March, 1848, in more favourable weather, the spiral form was distinctly seen in an oblique direction. The nebula was well resolved, particularly towards the centre, where it was very bright.

Another most extraordinary spiral nebula is shown in fig. 35, p. 17. It has been the subject of examination by all eminent observers

Fig. 33.

Fig. 34.



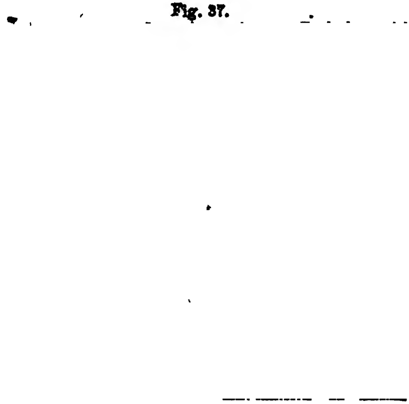
since the time of Messier, in whose catalogue it is No. 99. The spiral form of the nebula, represented in fig. 32, was discovered by Lord Rosse, in the early part of 1845. In the spring of 1846, that represented in the present figure was discovered. The spiral form is here also presented, but of a different character. Lord Rosse conjectures, that the nebula No. 2370, and 3239 of Herschel's southern catalogue, are very probably objects of a similar character. As Herschel's telescope did not reveal any trace of the form of this nebula, it is not surprising that it did not disclose the spiral form presumed to belong to the others, and it is not, therefore unreasonable to hope, according to his lordship, that whenever the southern hemisphere shall be re-examined with instruments of greater power, these two remarkable nebulæ will yield some interesting results.

Lord Rosse has discovered other spiral nebulæ, but they are comparatively difficult to be seen, and the greatest powers of the instrument are required to bring out the details.

In fig. 36 is another nebula having the spiral character, and a most singular form. Its situation is R A $1^h\ 24^m$ N P D $60^\circ\ 31'$, and is therefore in the northern part of the constellation Pisces. It is of great magnitude, having a diameter not less than half that of the moon. This object has been the subject of observation by all the eminent observers. Sir John Herschel describes it as enormously large, growing very gradually brighter towards the middle, and having a star of the 12th magnitude, north, following the nucleus, and being characterised by irregularities

of light, and even by feeble subordinate nuclei and many small stars. The drawing represents it as seen with the more powerful

Fig. 37.



telescope of Lord Rosse. A tendency to a spiral form was distinctly seen on the 6th, 10th, and 16th September, 1849. The whole object was involved in a faint nebulosity, which probably extends past several knots which lie about it in different directions.

86. The forms and magnitudes of the nebulæ are so infinitely various, that it is impossible to reduce them to any definite classification. Their number also is quite unbounded. The catalogues of Sir J. Herschel contain above 4000, of which the places are assigned, and the magnitudes, forms, and apparent characters described. As observers are multiplied, and the telescope improved, and especially when the means of observation have been extended to places that are more favourable for such observations, it may be expected that the number observed will be indefinitely augmented.

87. In fig. 37, we have reproduced the drawing of a well-known nebula by Sir John Herschel. This has been called, from its apparent form, the Dumb Bell nebula. Its situation is R A $19^h\ 52^m$ N P D 67° 44′, and consequently between the constellations of Vulpa minor and Lyra. Sir John Herschel describes it as a nebula shaped like a dumb-bell, double-headed shot, or hour-glass, the elliptic outline being completed by a more feeble nebulous light. The axis of symmetry through the centres of the two chief masses inclined at 30° to the meridian. Diameter of elliptic light from 7′ to 8′. Not resolvable, but four stars are visible on it, of the 12th, 13th, and 14th magnitude. The southern

the optical image. If on that occasion a second eye-piece had been used of lower power, the intermediate nebulous matter would have been seen, as represented in the drawing, and the drawing would be as perfect as, and nearly identical with, that

Fig. 41.

Fig. 42.

obtained with the greater telescope, a lower power being used.

Fig. 43.

Fig. 44.

It will be observed that the general outline of this remarkable object which is so geometrically exact as seen with the inferior power used by Sir John Herschel, is totally effaced by the appli-

cation of the higher powers used by Lord Rosse, and consequently Sir John Herschel's theoretical speculations based upon this particular form, must be regarded as losing much of their force, if not wholly inadmissible; and this is an example proving how unsafe it is to draw any theoretical inferences from apparent peculiarities of form or structure in these objects, which may be only the effect of the imperfect impressions we receive of them, and which, consequently, disappear when higher telescopic powers are applied. The case of the nebula represented in figs. 31 and 32, presents another striking example of the force of these observations.

88. In fig. 40 is a nebula drawn by Sir J. Herschel, who describes it as a faint large round nebula, which, by attentive examination, may be seen to be composed of excessively minute stars, appearing like points rubbed out. It is, in fact, a globular cluster.

In fig. 41, is a nebula situated in R A $22^h\ 56^m$, N P D $78°\ 36'$, and therefore in the southern part of the constellation of Pegasus. The length of this, as estimated by Sir J. Herschel, is $2'$, or the 15th part of the moon's diameter, while the breadth is only half a minute, or the 60th part of the breadth of the lunar disk. It is shown in fig. 41 as it appeared in the telescope of Sir J. Herschel. It is described by him as pretty bright and resolvable, and extended between two small stars, having two very small stars visible in it.

In fig. 42 is shown the same object as seen in Lord Rosse's telescope. It was frequently observed, both by Lord Rosse himself and several of his friends, and the drawing represents the form with great accuracy. It was doubtful whether the form was strictly spiral, or whether it were not more properly annular.

In fig. 43 is shown a double nebula situate in R A $7^h\ 15^m$, N P D $60°\ 11'$, and therefore near the bright star Castor. It is drawn by Sir J. Herschel, who describes it as a curious bright double or an elongated bicentral nebula.

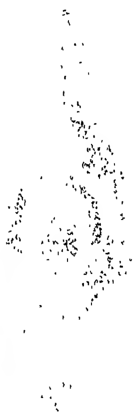
In fig. 44 is the same object as shown by Lord Rosse's telescope on 22nd December, 1848. A bright star was visible between the nebulæ from which tails and curved filaments issued. The existence of an annulus surrounding the two nebulæ was suspected.

In figs. 45, 46 are views of the same nebula, as seen by Sir J. Herschel and Lord Rosse. This object is situate in R A $11^h\ 10^m$. N P D $75°\ 59'$, and therefore between the two brightest stars of the constellation Leo. Its length is $4'$ or about the 7th of the moon's diameter. It is described by Sir John Herschel as large, elliptical in form, with a round nucleus, and growing gradually brighter towards the middle.

In fig. 46 it is given as shown by Lord Rosse's telescope, 31st March, 1848. Described as a curious nebula, nucleus resolvable, having a spiral or annular arrangement about it. It was also observed with the same results on the 1st and 3rd April.

Fig. 45.

Fig. 46.



A nebula, situate in R A $15^h\ 2^m$, N P D 33° 35′, is shown in fig. 47, its length being 50″ and breadth 20″.

This nebula was not figured by Sir John Herschel; but is described by him as an object very bright, and growing much brighter towards the middle. The drawing represents the object as seen in Lord Rosse's telescope, in April, 1848. It is described by Lord Rosse as a very bright resolvable nebula, but that none of the component stars could be distinctly seen even with a magnifying power of 1000. A perfectly straight longitudinal division appears in the direction of the major axis of the ellipse. Resolvability was strongly indicated towards the nucleus. According to Lord Rosse, the proportion of the major axis to the minor axis was 8 to 1; much greater than the estimate of Sir John Herschel.

In figs. 48, 49 are given two views of the same nebula by Sir J. Herschel and Lord Rosse. Its situation is R A $12^h\ 33^m$, N P D

56° 30′. It is therefore near the northern limit of the Coma Berenices. It is described by Sir John Herschel as a nebula of

Fig. 47

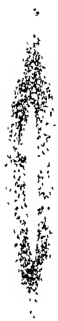


Fig. 48.

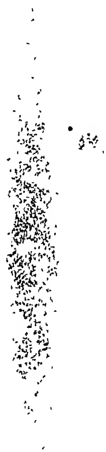
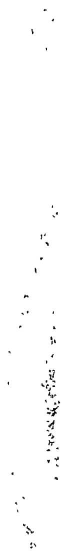


Fig. 49



enormous length, extending across an entire field of 15′, the nucleus not being well defined. It was preceded by a star of the tenth magnitude, and that again by a small faint round nebula, the whole forming a fine and very curious combination.

Fig. 49 is the same object as shown by Lord Rosse's telescope on 19th April, 1849. The drawing is stated to be executed with great care, and to be very accurate. A most extraordinary object, masses of light appearing through it in knots.

In fig. 50, p. 33, is represented a nebula situate in R A 6^h 30^m, N P

D 81° 30′. It is therefore situate about midway between the bright star Procyon and the shoulders of the constellation Orion. This object is described by Sir John Herschel as a star of the 12th magnitude, with a bright cometic branch issuing from it, 60″ in length, forming an angle of 60° with the meridian, passing through it. The star is described as ill-defined, the apex of the nebula coming exactly up to it, but not passing it.

Fig. 51, p. 33, is the same object as seen with Lord Rosse's telescope on 16th January, 1850. Lord Rosse observed that the two comparatively dark spaces, one near the apex and the other near the base of the cone, are very remarkable.

In fig. 52, p. 193, Vol. vii., is represented a nebula situated in R A 11^h 5^m, N P D 34° 3′, having a diameter equal to about the 90th part of that of the moon. It is drawn and described by Sir John Herschel as a large uniform nebulous disk, very bright and perfectly round, but sharply defined, and yet very suddenly fading away into darkness. A most extraordinary object.

Fig. 53, p. 193, Vol. vii., is the same object as shown by Lord Rosse's telescope. Two stars considerably apart, seen in the central part of the nebula. A dark penumbra around each spiral arrangement with stars as apparent centres of attraction. Stars sparkling in it and in the nebula resolvable. Lord Rosse saw two large

Fig. 54.

Fig. 55.

and very dark spots in the middle, and remarked that all round its edge the sky appeared darker than usual.

In fig. 54 is represented a nebula situated in R A 23^h 18^m, N P D 48° 24′, as drawn by Sir John Herschel, who describes it as a fine planetary nebula. With a power of 240 it was beautifully defined, light, rather mottled, and the edges the least in the world unshaped. It is not nebulous, but looks as if it had a double outline, or like a star a little out of focus. It is perfectly circular.

Fig. 55 is the same object as shown in Lord Rosse's telescope, 16th—19th December 1848. A central dark spot surrounded by a bright annulus.

In fig. 56, p. 1, vol. viii., is a nebula situate in R A 20^h 54^m, N P D 102° 3′. Diameter 10″ to 12″ according to Herschel, but 25″ by 17″ according to Struve, who gives it a more oval form. This figure is that given by Sir John Herschel, who describes it as a fine planetary nebula with equable light and bluish white colour.

Fig. 57, p. 1, vol. viii., is the same object as shown by Lord Rosse's telescope. Like a globe surrounded by a ring such as that of Saturn, the usual line being in the plane of the ring.

In fig. 58 is a nebula drawn by Sir J. Herschel, situate in R A

Fig. 58.

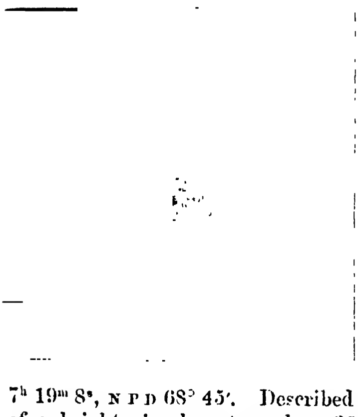
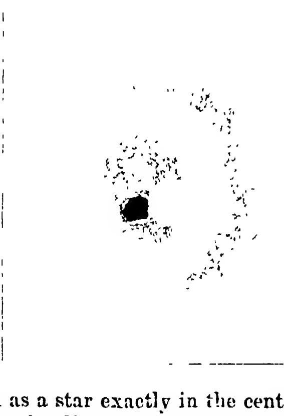


Fig. 59.



7^h 19^m 8^s, N P D 68° 45′. Described as a star exactly in the centre of a bright circular atmosphere 25″ in diameter, the star being quite stellar, and not a mere nucleus, and is a most remarkable object.

Fig. 59 is the same object as shown by Lord Rosse's telescope on 20th February, 1849; described by him as a most astonishing object. It was examined in January 1850, with powers of 700 and 900, when both the dark and bright rings seemed unequal in breadth.

In fig. 60 is represented a drawing by Lord Rosse, made with his large telescope, of a nebula situate in R A 5^h 27^m, N P D 96° 2′. This nebula surrounds the small star ι Orionis, and has a diameter equal to about a tenth part of that of the moon.

Fig. 60.

89. All the nebulæ described above are objects generally of regular form, and subtending small visual angles. There are others, however, of a very different character, which cannot be passed without some notice. These objects cover spaces on the firmament, many nearly as extensive as, and some much more extensive than, the moon's disk. Some of them have been resolved. Of those which are larger and more diffused, some exhibit irregularly shaped patches of nebulous light, affecting forms resembling those of clouds, in which tracts are seen in every stage of resolution, from nebulosity irresolvable by the largest and most powerful telescopes, to stars perfectly separated like parts of the milky way, and "clustering groups sufficiently insulated and condensed to come under the designation of irregular and, in some cases, pretty rich clusters. But, besides these, there are also nebulæ in abundance, both regular and irregular; globular clusters, in every state of condensation, and objects of a nebulous character quite peculiar, which have no analogy in any other part of the heavens."*

* Herschel, Outlines of Astronomy, p. 613.

90. The star ω Centauri presents one of the most striking examples of the class of large diffused clusters. It is nearly round, and has an apparent diameter equal to two-thirds of that of the moon. This remarkable object was included in Mr. Dunlop's catalogue ("Phil. Trans." 1828); but it is from the observations of Sir John Herschel, at the Cape, that the knowledge of its splendid character is derived. That astronomer pronounces it, beyond all comparison, the richest and largest object of the kind in the heavens. The stars composing it are literally innumerable; and as their collective light affects the eye hardly more than that of a star of the fifth magnitude, the minuteness of each of them may be imagined. The apparent magnitude of this object is such that, when it was concentric with the field of Sir J. Herschel's 20-feet telescope, the straggling stars at the edges were beyond the limit of the field. In stating that the diameter is two-thirds of the moon's disk, it must be understood to apply to the diameter of the condensed cluster, and not to include the straggling stars at the edges. When the centre of the cluster was brought to the edge of the field, the outer stars extended fully half a radius beyond the middle of it.*

The appearance of this magnificent object resembles that shown in fig. 18, only that the stars are much more densely crowded together, and the outline more circular, indicating a pretty exact globe as the real form of the mass.

91. *The great nebula in Orion.*—The position of this extraordinary object is in the sword-handle of the figure which forms the constellation of Orion. It consists of irregular cloud-shaped nebulous patches, extending over a surface about 40′ square; that is, one whose apparent breadth and height exceed the apparent diameter of the moon by about one-third, and whose superficial magnitude is, therefore, rather more than twice that of the moon's disk. Drawings of this nebula have been made by several observers, and engravings of them have been already published in various works.

In fig. 61 is given a representation of the central part of this object. The portion here represented has a height and breadth about one-sixth less than the diameter of the moon. An engraving upon a very large scale, of the entire extent of the nebula, with an indication of the various stars which serve as a sort of landmarks to it, may be seen by reference to Sir J. Herschel's "Cape Observations," accompanied by the interesting details of his observations upon it.

Sir J. Herschel describes the brightest portion of this nebula as

* Cape Observations, p. 21.

resembling the head and yawning jaws of some monstrous animal, with a sort of proboscis running out from the snout. The stars scattered over it probably have no connection with it, and are doubtless placed much nearer to our system than the nebula, being visually projected upon it. Parts of this nebula, when submitted to the powers of Lord Rosse's telescope, show evident indications of resolvability.

92. An object of the same class is shown in fig. 62, p. 177, Vol. vii., and presenting like appearances; it is diffused around the star η in the constellation Argo, and formed a special subject of observation by Sir J. Herschel, during his residence at the Cape. An engraving of it on a large scale, giving all its details, may be seen in the "Cape Observations." The position of the centre of the nebula is, R A 10° 38′ 38″, N P D 148° 47′.

This object consists of diffused irregular nebulous patches, extending over a surface measuring nearly 7^m in right ascension, and 68′ in declination; the entire area, therefore, being equal to a square space, whose side would measure one degree. It occupies, therefore, a space on the heavens about five times greater than the disk of the moon.

The part of the nebula immediately surrounding the central star, is represented in fig. 62. The space here represented measures about one-fourth of the entire extent of the nebula, in declination, and one-third in right ascension, and about a twelfth of its entire magnitude.

No part of this remarkable object has shown the least tendency to resolvability. It is entirely compressed within the limits of that part of the milky way which traverses the southern firmament, the stars of which are seen projected upon it in thousands. Sir J. Herschel has actually counted 1200 of these stars projected upon a part of this nebula, measuring no more than 28′ in declination, and 32′ in right ascension, and he thinks that it is impossible to avoid the conclusion, that in looking at it we see through and beyond the milky way, far out into space through a starless region, disconnecting it altogether with our system.

93. The Magellanic clouds are two extensive nebulous patches also seen on the southern firmament, the greater called the *nubecula major*, being included between R A 4^h 40^m, and 6^h 0^m and N P D 156° and 162°, occupying a superficial area of 42 square degrees; and the other called the *nubecula minor*, being included between R A 0^h 21^m and 1^h 15^m and between N D P 162° and 165°, covering about 10 square degrees.

These nebulæ consist of patches of every character, some irresolvable, and others resolvable in all degrees, and mixed with

clusters; in fine, having all the characters already explained in the cases of the large diffused nebulæ described above. So great is the number of distinct nebulæ and clusters crowded together in these tracts of the firmament, that 278, besides 50 or 60 outliers, have been enumerated by Sir J. Herschel, within the area of the nubecula major alone.

Fig. 20.—Caucasian.

COMMON THINGS.

MAN.

CHAPTER I.

1. Physical condition of Man generally neglected.—2. The brain the organ of intelligence.—3. General view of the nervous system.—4. Structure of the brain.—5. The Facial Angle.—6. Its variation in different animals.—7. Recognised as an indication of intellectual power.—8. The advantages Man derives from the form of his members.—9. Prehensile and locomotive members.—10. Structure of the hand.—11. The bones of the arm and hand.—12. Wonderful play of the muscles and the movement of the fingers; example of piano-forte playing.—13. The lower members.—14. The leg and foot.—15. The erect position proper to man.—16. Man alone bimanous and bipedous.—17. Quadrumana.—18. Power of language.

1. Although it has been affirmed and quoted by generation after generation that

"The proper study of mankind is man,"

that study, even among the most cultivated, has been confined too exclusively to the social and political condition of our race, to the total neglect of the physical relations by which it is connected with the inferior species. Although these relations exhibit

in a striking point of view all that we have in common with the rest of the animal kingdom, they render manifest not less conspicuously those which set us apart from, and exalt us above them. So profoundly impressed was the greatest of modern naturalists with the force of the evidence of man's superiority, derived merely from his physical organisation, that he maintained that, even according to the rigorous principles of inductive science based on physical and mechanical phenomena, without taking into consideration the possession of the reasoning faculty, man ought to be classified, not as a species of the order of vertebrated animals, but as an order apart, distinct from and independent of all other parts of organised nature, and presenting the anomalous example of being the sole genus of his order and the sole species of his genus.*

Nevertheless, our physical organisation differs but little in appearance from that of a considerable number of Mammifers,† that is, of the animals which suckle their young. The functions of nutrition with us and with them are alike, and the structure of the organs of sense present but few distinguishing peculiarities. Yet man is placed immeasurably above all other organised beings, a superiority which he owes, not altogether to the gift of reason and of language, but also, in a great degree, to the mechanical conformation of his members.

2. Physiologists have traced a general relation between the degree of intelligence manifested by different organised beings, and the volume and structure of the brain, not only when species is compared with species, but when individual is compared with individual: and some have pretended to push this induction even so far as to connect different parts of the brain with different faculties, passions, and tendencies, founding their conclusions partly on observations of the human brain in connection with the development of human character, and partly on the analogies observable between the human brain, passions, and tendencies, compared with the brain, passions, and tendencies of inferior animals. Hence has arisen that new branch of inquiry claiming a place in physiological science under the name of Phrenology.

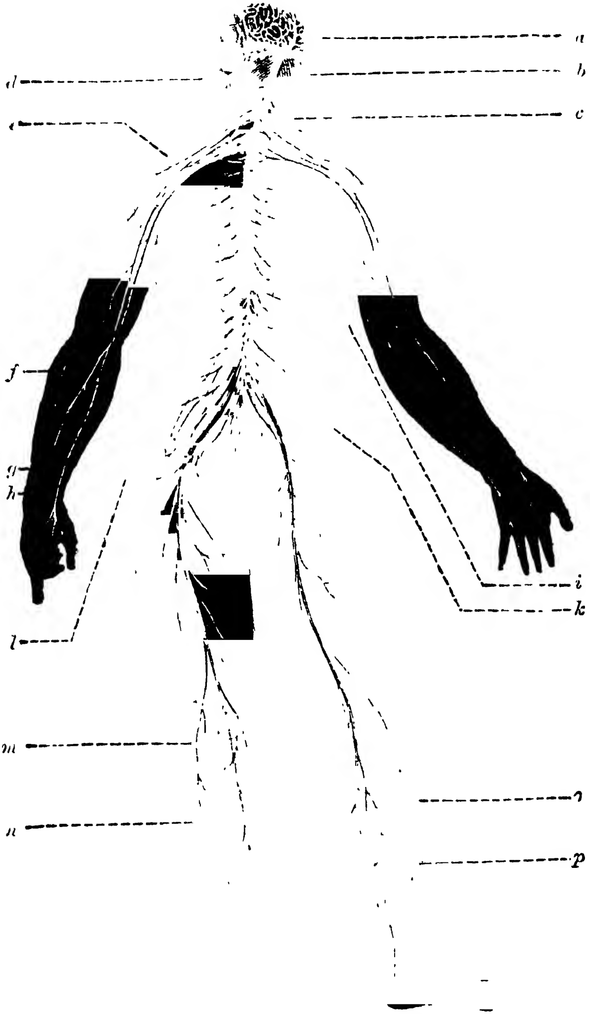
However questions of this order may be decided, it has never been doubted that the brain is the organ of intelligence, thought, and feeling. It is the centre of the nervous system, and is connected with all parts of the body by thousands of nervous filaments.

3. Some notion of the manner in which these diverge from the brain and from all parts of the spinal cord, and ramify over all

* Cuvier.

† From *mamma*, a "pap, or teat," and *fero*, "I bear."

the organs and members, may be obtained by the annexed figure, where *a* is the brain; *b*, the posterior part of that organ, called



the *cerebellum*; *c*, the spinal cord; *d*, the branch of nerves which ramifies over the face; *e*, that which goes to the arm; *f*, *g*, *h*,

its ramifications over the lower arm and hand; *i*, those which spread over the trunk; *k*, *l*, those which lead to the leg and thigh; *m*, *n*, *o*, *p*, their ramifications over the leg and foot.

The innumerable nervous filaments which are thus spread over the entire system, and which at length become so minute as to be microscopic, are the messengers of thought, carrying the dictates of the will from the brain to all the members, which move in most

Fig. 1.—View of the inferior surface of the human brain, divested of its membranous coatings.

absolute obedience to the commands thus received. They are also the conductors of sensation from all parts of the system to the brain, and are therefore divided into two classes; the first consisting of those which, carrying the dictates of the will to the movable members, are called *nerves of motion;* and the second, of those which, conveying sensation from all parts of the body to the brain, are called *nerves of sensation.* The practical proof that each of these classes of nerves is invested with the special functions here ascribed to them, is found in the fact, that if

a nerve of motion be cut, the member which it moves will be immediately paralysed; and if a nerve of sensation be cut, the part which it connects with the brain will become insensible. Thus, for example, if the nerves of motion proceeding from the brain to the arm be divided at the shoulder, the entire arm and hand will be paralysed, the will losing all power over it. In like manner, if the nerve connecting the optical membrane of either eye be divided at any point between that membrane and the point where the nerve unites with that which proceeds from the other eye, the former eye will become blind, the sight of the latter remaining unimpaired. But if the optic nerve be divided beyond

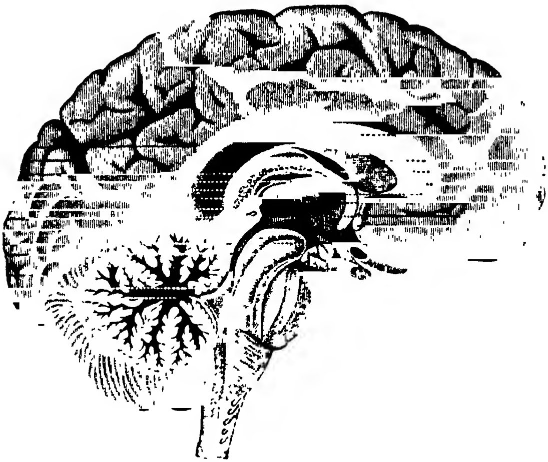


Fig. 2.—Section of the human brain made by a vertical plane passing through the middle of the forehead.

the point where the nerves from the two eyes are united, both eyes will lose the power of vision.

4. The brain being the organ of intelligence, it has, as might naturally be expected, a greater development and more perfect structure in man than in the inferior animals. The *cerebral hemispheres*, as they are called, are more voluminous, and their convolutions are more prominent and numerous, and extended over a much larger region of the skull. They cover, for example, that part of the organ called the *cerebellum*, while in inferior animals they never extend over it, and in many cases have no existence at all.

The part of the brain which occupies the front of the skull in man is remarkable for the extent of its volume, and gives that

peculiar elevation to the forehead and nobleness of aspect which is nowhere to be found among the inferior species.

5. The proportion which the part of the head occupied by the principal organs of sense,—those of seeing, hearing, smelling, and tasting,—bears to the part occupied by the brain and its appendages, is found to be a good general modulus of the power of the intellectual faculties; and accordingly methods have been sought by physiologists, by which this proportion can be conveniently ascertained with some degree of approximation by external indications, independently of the results of dissection. The method which has been most generally received is that proposed by Camper, an eminent Dutch naturalist, which consists in measuring what he called the *facial angle*, formed by a line, *c d*, (fig. 3)

Fig. 3.

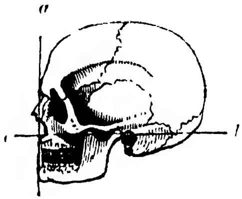
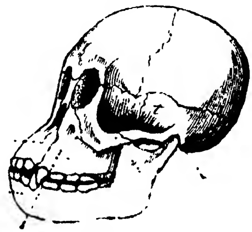


Fig. 4.



drawn through the opening of the ear and the base of the nostrils, with another line, *a b*, drawn from the most salient point of the forehead, through the front of the upper jaw. This angle will be greater or less, according to the greater or less development of the brain, especially in its anterior part.

In comparing man with the inferior animals, it is found accordingly, that the facial angle exceeds those of the latter in a large proportion; and in comparing different species of animals one with another, the variation of this angle is in remarkable accordance with their several manifestations of intelligence.

6. The following are the facial angles of certain species, according to different physiological authorities:—

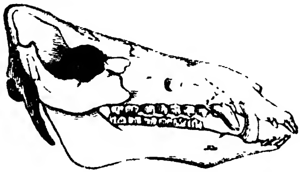
Man (European) (fig. 3)	85° to 90°
Ouran-Outang (fig. 4)	56° to 60°
Apes (fig. 5)	30° to 65°
Dog	35°
Ram	30°
Horse	23°

According to Professor Milne Edwards, the forehead in the case of the wild boar (fig. 6) is so falling, that it is impossible to draw a straight line from the upper jaw to the most prominent

part of the skull, the latter falling considerably behind the bony projection of the nose.

Fig. 5.

Fig. 6.



With birds and fishes the facial angle is less than with mammifers, and with reptiles, as in the crocodile (fig. 7), is often so small as to be scarcely appreciable.

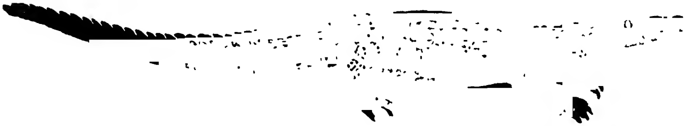
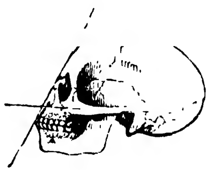


Fig. 7.—Crocodile.

In comparing individuals of the human race existing in different climates and under different physical influences, the facial angle is subject to much variation. Thus, while with the European (fig. 3) it is sometimes so great as 90°, with the negro (fig. 8) it seldom exceeds 70°.

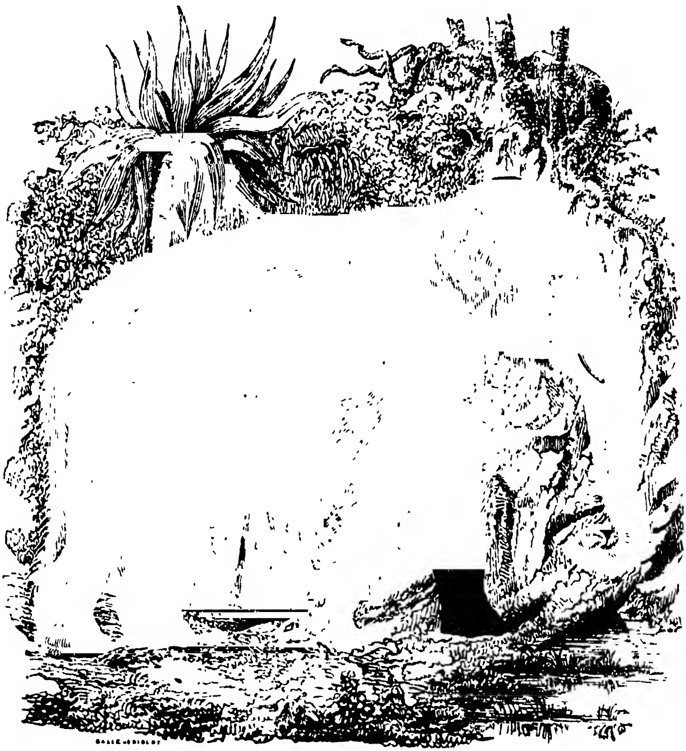
Fig 8.



7. Although the more complete investigation of the connection of cerebral development with the extent of the intellectual faculties was reserved for modern investigators, it does not appear to have escaped the notice of the ancients, who evidently saw in the facial angle an index of intelligence. Not only do we find in their writings an erect frontal line noticed as a mark of a generous nature and an essential character of beauty, but the ancient sculptors conferred upon the figures of their heroes and their gods a facial angle much larger than is ever seen in man; and in some of the more remarkable statues which have come down to us,—the Olympian Jupiter for example,—the frontal line *b a*, fig. 3, actually inclines forwards so as to render the facial angle obtuse.

Even the most vulgar observation ascribes stupidity to a projecting mouth and nose and retiring forehead, to which the name *muzzle* is given, whether found in men or in animals. And when

in exceptional cases an apparent enlargement of the facial angle is produced by a prominence of the bony arch which protects the eyes, a spurious air of intelligence is produced, which causes qualities to be ascribed to animals having this conformation, which they do not really possess. The elephant (fig. 9) and the owl (fig. 10) are examples of this.



Owing to the peculiar expression thus given, the owl, as is well known, was adopted by the ancients as the symbol of wisdom, and the Indian elephant bears an oriental name which implies the possession of a certain share of reason.

8. The brain, however, is not the only part of his organism, to which man owes his great superiority; the conformation of his members, combined with his intellectual powers, gives him a

dominion over the inferior species, which he never could obtain by his natural strength or swiftness.

Like that of the superior classes of Mammifers generally, the human body is supplied with four members; the superior, or arms and hands, and the inferior, or legs and feet. It is found in the works of nature, as in those of art, that the more extensively the principle of the division of labour is carried out, the greater will be the perfection of the instruments. A tool or a machine, which attains two purposes, attains neither of them so perfectly as would two tools or machines especially adapted to the execution of each. Now we find, on comparing man with the inferior animals, that he supplies a solitary example of the rigorous application of the principle of the division of labour in the functions of his members. The necessities of its well-being require that the creature should be supplied with members to seize and members to pursue the objects of its nutrition. Hence arises the necessity for members of prehension and members of locomotion. In some of the inferior animals, as, for example, certain quadrupeds, the four members are exclusively locomotive, the act of prehension being confined to the mouth. In others, however, all the four members, besides fulfilling the functions of locomotion, are more or less prehensile, thus serving a double purpose, and therefore, according to the principle explained above, serving it by comparison less perfectly. In some, the prehensile functions of the four members prevailing over their locomotive functions, naturalists have given them the name of *quadrumana*, or four-handed, in contradistinction to that of quadrupeds, or four-footed, given to those species whose members are more exclusively locomotive.

Fig 10.

9. In man alone are found at once members which are exclusively prehensile, and others exclusively locomotive.

10. The superior members are disposed in a manner most favourable for prehension and touch. By the peculiar mechanism of the shoulder-joint, the arm can be directed with nearly equal facility upwards, downwards, forwards, and backwards. The fore-arm at the same time being hinged upon the elbow, and the hand upon the wrist, a still more varied play is given to the hand, the immediate instrument of prehension. But even with this

variety of motion and inflection, something would still be wanting. The chief seat of the sensibility of touch is the palm of the hand and the palmar sides of the fingers; and the mechanism of the hand is so contrived as to accommodate itself to the play of this sensibility. The thumb is mounted so as to face the fingers, and the articulations of both are such as to enable them to be inflected towards each other, and towards the palm, so that when an object is embraced or grasped by the fingers, all the part of the hand possessing most sensibility of touch is brought into contact with it. If we grasp the hand of a friend or a beloved relative, the palms come into contact, and we are conscious of a mutual sensation conveyed through the nervous system. If, while the mechanism of the hand remains the same, the nerves which now overspread the palm and the palmar sides of the fingers were spread over the back of the hand, all this sensibility would cease.

It is obviously essential that the palm of the hand, which is thus its prehensive side, should be capable of being turned in all directions, so as to present itself to the objects to be grasped or touched. But the hinge joints of the wrist and elbow would only enable the palm to be inflected inwards towards the hollow of the arm.

It is true that the rotatory motion which can be given to the arm upon the shoulder would vary the play of the palm, but the motion would still be imperfect for the purposes of prehension and touch. An expedient is, therefore, provided, which may be fairly said to confer upon the hand the utmost perfection as an organ of prehension. This expedient consists of a simple and beautiful mechanical arrangement in the structure of the fore arm, which is composed between the elbow and wrist, not of one, but of two bones, of nearly equal length, placed side by side. One of these, called the *ulna*, is articulated with the upper bone of the arm at the elbow by a hinge joint; the other, called the *radius*, is articulated to the hand at the wrist, with a like hinge motion. But the radius having the hand thus appended to it is so arranged that it can revolve round the ulna, carrying the hand with it, thus having the faculty of presenting the palm in any desired direction without changing the general position of the arm.

11. In fig. 11, the bones of the arm and hand are represented; the ulna, hinged upon the elbow, being on the left, and the radius, with the hand hinged upon it at the wrist, being on the right. The two bones are tied together by intermediate ligaments (6, 7), the ligament by which the hand is tied to the radius appearing at 10. The palm of the hand and the hollow of the elbow are supposed to be presented to the observer.

When to all these conditions it is added that the successive

bones of the fingers gradually decrease in length; that they are articulated with a succession of hinge joints; that they are moved independently, one of another, by a series of muscles acted upon by nerves which are under the complete dominion of the will, the admirable perfection of the organ of prehension and touch may be in some degree appreciated.

Fig. 11

12. When the movements of the arm, hand, and fingers, are considered collectively, it may be stated, without exaggeration, that in directing the fingers to any object of touch, a hundred muscles are brought into operation, whose contractile power is excited by thousands of nervous filaments, each of which is under the absolute dominion of the will, each action of volition requiring a corresponding intellectual exertion. How wondrous this machinery intellectual, physiological, and mechanical, must be, the least reflection upon the manual exercises which are daily performed, especially in civilised and polished life, will render manifest. When a performer, for example, executes upon the piano-forte one of the complicated compositions of the modern composers for that instrument, as many as ten thousand notes must be produced by the application of the fingers to the keys. The longest of these pieces is executed in about 15 minutes, or, in round numbers, 1000 seconds, so that the notes must be produced at the rate of 10 per second, and as each note requires a separate dictate of the will, and each dictate of the will a separate act of the mind, we arrive at the surprising conclusion that these mental acts are performed in this particular case at the rate of 10 per second. Nor can it be said that habit enables the fingers to move mechanically while the mind is passive, and that the facility given by repetition supersedes mental action; for artists are found so expert as to execute such pieces at sight, never having previously studied them.

13. The lower members are as eminently fitted for the purposes of support and locomotion as are the superior for prehension. Attached to the hip bones or pelvis, at the external corners, they are so articulated as to have a certain play forward, backward,

and laterally, sufficient for the purpose of locomotion, yet not too great for stability.

While the arm at the shoulder plays in an extremely shallow socket, so as to give it all that vast range of motion which is necessary in an organ of prehension, but would be altogether incompatible with one of sustentation, the thigh bone is articulated at the hip in a deep spherical socket, which looks obliquely downwards, and which rests upon the convex head of the bone with sufficient firmness and solidity to afford a secure support to the incumbent weight of the trunk, the upper members, and the head.

14. The leg is articulated to the thigh at the knee by a hinge joint, which enables it to be inflected backwards, so as to accommodate itself to a progressive motion. Unlike the hand, the foot has no rotatory motion on the leg; the two bones composing which, firmly united together, confine between them the upper bone of the foot, forming the ankles at either side of it. The foot thus moves with a hinge motion on the ankle joint, projecting backwards at the heel, and still further forward in the direction of the toes, so as to supply a large basis for the support of the body.

The toes, unlike the thumb and fingers, are totally incapable of prehension; the great toe, which corresponds to the thumb, instead of facing the others, is placed in juxtaposition with them, and they cannot therefore be brought together so as to form, like the fingers and thumb, a sort of pincers.

The sole of the foot corresponds to the palm, and the instep to the back, of the hand. The bones of the latter, extending obliquely from the bend of the ankle joint to the commencement of the toes, form an elastic arch, by which the blood-vessels, nerves, and muscles of the foot are protected from the pressure of the weight of the body, which would otherwise crush them. The fleshy mass formed by the muscles and fat placed upon the sole constitutes a cushion or buffer, which softens the collision which must otherwise take place each time that the foot comes to the ground, with the whole weight of the body upon it.

15. Everything in the mechanical structure of the body conspires to prove that man was made to stand erect; and with this erect position are associated numerous consequences connected with his superiority over other species. His feet are formed with a base which is large in proportion to his body, so that the centre of gravity can be easily kept vertically over it, a condition which is essential to his stability. The legs, in their natural position, are placed at right angles to the soles of the feet, and are therefore vertical when the latter are horizontal. The centre of gravity of the trunk is at some distance in front of the spinal column, and would therefore have a tendency to incline forward, so that the

body would take the position of that of a quadruped, in which the spinal column would be horizontal, the upper part of the trunk being supported by the arms, the hands performing the duties of fore-feet. But this is prevented by the establishment along the whole extent of the back of several layers of powerful muscles, which tie the vertebræ together, two and two, three and three, four and four, and so on. The tone of these muscles is such, that their normal tension produces a force which equilibrates with the weight of the trunk acting at its centre of gravity in front of the spine. These muscles have a power of contraction and relaxation within certain limits, by which the body can be inclined backwards or forwards, more or less. The head is mounted upon the summit of the vertebral column, forming as it were its capital, in a manner obviously adapted for the vertical position. Like the trunk, its centre of gravity is a little in front of the summit to the spinal column, and therefore it would have a tendency to incline forwards, but this as before is resisted by muscles of adequate power placed on the back of the neck.

Nothing more manifestly indicates the intention of nature that man should stand erect, than the position of his face and the direction of his optic axes. In the erect position his face looks forwards, and the optic axes are horizontal. But if he were to assume the prone position, supported by his four members like a quadruped, the optic axes would be directed downwards, and, except by a strained effort of the neck, he could not see before him. To this it may be added, that the knee joint being so constructed that the leg can only be deflected backwards on the thigh, would render the legs utterly unfitted to be members of support and locomotion in the prone position, since in that case the point of support would be, not the feet, but the knees. Now, independently of the consideration that in this case the legs and feet would not only become useless, but would be an impediment to every act of locomotion, the shortness of the thigh would inconveniently limit the power of progression, the thin integuments covering the knee-pan would soon be destroyed by the pressure upon it, and the knee-pan itself, a loose and detached bone, would be displaced, and the members totally disabled.

It would not be worth while to insist upon these particulars, were it not that some authors, impelled doubtless by the love of paradox, have maintained that the prone position is natural to man, and the erect position the result of education.

16. Man, then, alone presents the characters of a *bimanous* and *bipedous* animal. The various species of apes, who approach so close to him in some respects, differ from him essentially in their members, their inferior or posterior members having as much the

character of hands as of feet, and their anterior members as much the character of feet as of hands.

In fig. 12 is represented the species of ape called the chimpanzee, using the anterior member as a prehensile organ. In fig. 13 another species of quadrumana is shown, where the conformation of all the four feet closely corresponds with that of the human hand, but all the four are used for support and locomotion.

It is evident that the mode of locomotion to which the mixed character of the hand and foot found in the quadrumana is best adapted, is that of climbing, to which accordingly the monkey tribes are more especially addicted, often carrying their young clinging round their bodies as they mount.

Fig 12.—The Chimpanzee.

Fig 13.—The Mandrill.

In fig. 14, a monkey called the *maki*, a species of lemur, is represented in one of its habitual attitudes, carrying its young.

17. The double purpose of prehension and locomotion assigned to the members of the quadrumana, and their habitual exercise of climbing in pursuit of their food and for protection from their enemies, renders the occasional aid of another organ of prehension necessary; such an organ is accordingly supplied them in the tail. In fig. 15 is represented the White-throated Monkey thus exercising this prehensile action. The same action is common with the species called the *Coaita*, or Spider-Monkey, so named from the extraordinary length of its extremities, and from its motions. "The tail," says Sir Charles Bell, "answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging by the foot, sometimes by the fore extremity,

but oftener and with greater reach by the tail. The prehensile part of the tail is covered with skin only, forming an organ of touch as discriminating as the proper extremities. The *Caraya*, or Black Howling Monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so

Fig. 14.—The Maki.

struck with this property of the tail of the *Ateles*, that they have compared it to the proboscis of the Elephant, and have assured us that they fish with their tail.

"The most interesting use of the tail is seen in the opossum. The young of that animal mount upon her back, and entwine their tails round their mother's tail, by which they sit secure while she escapes from her enemies." *

It will be observed that the young one, represented in fig. 14, also uses its tail as an organ of prehension, holding itself upon the body of its mother by twining the tail round her.

* Bell, On the Hand, p. 20.

18. But of all the organs to which man owes his superiority, that of voice is incontestably the most important. He alone, among all created beings, is endowed with the power of producing

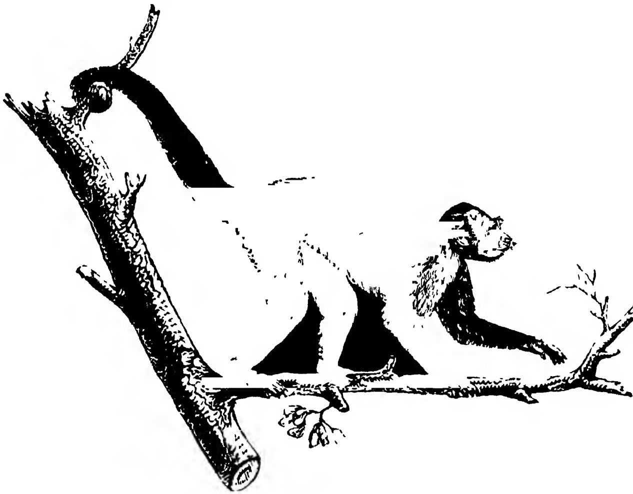


Fig. 15.—The White-Throated Monkey.

articulate sounds in infinite variety, and applying them to the expression of his thoughts, sentiments, and feelings. By this power he is enabled to communicate with his kind, to interchange with them the expressions of kindness and affection, and to impart and receive knowledge and information. Great as this power is, it is augmented in a manifold proportion by the device of expressing oral sounds by written or printed characters. By this expedient oral language becomes visible, and is, so to speak, perpetuated; the discourse which is spoken or listened to, however impressive may be the eloquence of the speaker, and however profound the attention of the hearer, may, and generally does, soon fade from the memory, but language printed or written is permanent,

Litera scripta manet,

and may be referred to again and again until the reader renders it his own.

The printed book can be handed down and reproduced indefinitely from age to age, and those of one generation are thus enabled to listen to the precepts and imbibe the counsels of the wisest and most virtuous of former times.

Fig. 21.—MONGOL.

COMMON THINGS.

MAN.

CHAPTER II.

19. Physical feebleness of man.—20. His helpless infancy.—21. His great power nevertheless.—22. Man gregarious.—23. His dentile apparatus.—24. Why nevertheless he uses animal food.—25. His migratory power and distribution over the globe.—26. View of his progress from the cradle to the grave.—27. Births.—28. Cases of two and three at a birth.—29. Births more prevalent at certain seasons.—30. Proportion of the sexes born.—31. Proportion in the case of illegitimates.—32. Chances of life more favourable for females.—33. Organs of sense in infancy—the eye.—34. The voice.—35. The bones.—36. Instinct in the infant.—37. Terror of falling.—38. Milk teeth.—39. Permanent teeth.—40. Their periods of emergence.—41. The average height of men.—42. Giants and dwarfs.—43. Average height of women.—44. The influence of race.—45. Influence of climate.—46. Hygienic conditions.—47. Their effects shown by conscription in France.—48. Rate of growth from infancy to maturity.—49. Progressive increase of bulk.—50. Organic changes at puberty.—51. Organic changes in the bones. 52. The muscles.—53. Examples of longevity.—54. Great mortality in infancy.

19. Man thus singularly favoured by the possession of reason, and by the address and precision of which the motions of his

members, and more especially those of the hand, are susceptible, is, nevertheless, in some of his physical attributes, immeasurably inferior to other animals which correspond with him nearly in size. He is neither swift of foot to pursue his prey or fly from his enemies; nor is he supplied with any natural weapons of attack or defence, such as those which are found among the numerous classes of animals around him. He is not only feeble and defenceless, but Nature has refused to provide him with those means of protection from the inclemency of the elements, which she has so beneficently supplied to those who hold a lower place in the chain of organised beings. He has neither the fur of the beast, nor the feathers of the bird, to protect him from the rigours of temperature, and yet his body is covered with a skin and teguments abounding in nerves, which render it ten thousand times more sensitive than the skin of any of these creatures which Nature has so carefully and tenderly protected.

20. In coming into the world, he is more helpless and delicate than the young of any other creature, and continues for a much longer period dependent, not for his well-being only, but for his very existence, upon the assiduous and never-ceasing solicitude and tenderness of his parents.

21. Yet this creature, thus naturally poor, feeble, naked, helpless, and defenceless, is the lord and master of the material world. By him the strongest is subdued, the fiercest tamed, the swiftest overtaken. He cannot rise into the air, nevertheless he arrests its inhabitants in their flight and brings them to his feet. He cannot descend into the waters, nevertheless he calls forth from the chambers of the deep their tenants, for the supply of his wants and the gratification of his appetites. His body is unprotected by any natural covering, but the beasts of the forest and the birds of the air are compelled to surrender for his use their fur and their plumage. Innumerable textile plants, which in their natural state would be unavailing, are adapted by his art to supply the materials by which clothing for his body can be made in unbounded quantity. Unable to endure the vicissitudes of temperature and climate, the earth itself is compelled to surrender its bowels, and to supply inexhaustible quantities of fuel, by which artificial heat is produced to moderate the rigours of cold and equalise temperature. He is not swift of foot to pursue or to fly, but he tames for his use the swiftest of subordinate creatures, which with the most absolute obedience transport him where he wills. Not satisfied even with this, his inventive powers have created engines of transport which carry him over the face of the waters, in spite of opposing wind and tide, and over the surface of the land, with a speed which

exceeds the flight of the swiftest bird and equals the rapidity of the tempest.

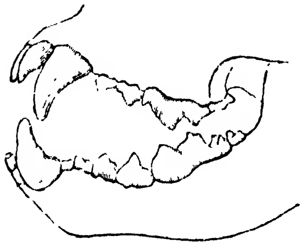
So far, then, from having reason to repine at his helpless and defenceless organisation, he is indebted to those apparent defects for the greatest of his attainments; for it is certain, that if he had possessed natural organs of defence, attack, and locomotion, and natural protection for his body at all analogous to those which have been provided so generally for the inferior species, he would have lost that strong stimulus which has urged him on to such stupendous and almost incredible achievements. Nor is this observation novel. At a much earlier epoch in the progress of the human race, and ages before the great discoveries had been made which will render for ever memorable the last hundred years, Galen observed, that if man had possessed the natural clothing and defence of the brute, he would never have been an artificer, nor protected himself with a cuirass, nor fabricated the sword or spear, nor invented the bridle, nor mounted a horse, nor hunted the beast. Neither would he have followed the arts of peace, nor constructed the pipe and the lyre, nor erected houses or palaces, nor temples to the gods; nor would he have made laws, nor invented letters by which he would hold communion with the wise of antiquity, conversing at one time with Plato, at another with Aristotle, and at another with Hippocrates.

22. The possession of the faculty of language necessarily infers the instinct of sociability, and man cannot live alone. He seeks the society of his kind, and belongs to the class which naturalists call *gregarious.* The advantages derived from this habit of association are infinite; without it, indeed, man, instead of being as he is, the monarch of nature, would be amongst the most miserable of animals, and would assuredly soon disappear from the earth. But by association every individual strengthens and supports others, and is strengthened and supported by them. Each cultivating some special faculty or power in a higher degree than his fellows, renders it serviceable to them, and receives in return equivalent services from those who have cultivated other powers in which he is deficient; and thus comes into play that vast principle of material production and social felicity known as the division of labour.

Like all other gregarious animals, man is naturally frugivorous, or made to live on fruit and vegetables. This is a conclusion not resting solely upon the analogy observable between man and other gregarious species, but supported by the characters of his organs of nutrition. The teeth of carnivorous species (fig. 16) are peculiarly formed for tearing and masticating the flesh which constitutes their proper food. The canine teeth are largely

developed, sharp and curved; and the incisors partake of the canine character. The teeth which occupy the place of molars, edged and sharp, close side by side like the blades of scissors. The dentile apparatus is thus adapted to tear and cut the flesh before it passes into the stomach. The teeth, on the contrary, of frugivorous animals consist of incisors and molars; the canine teeth existing, but so little developed as to have no functions different from those of incisors. The molars of the two jaws, nearly flat at their ends, come into direct contact and superposition like two millstones, and the jaws, by a small lateral motion, have the power not only of bruising but of grinding the food between them. These operations are all that is necessary and sufficient for vegetable, but would be altogether inapplicable to animal food.

Fig 16.



23. Every one will recognise in the dentile apparatus last described the form and structure of the human teeth; and so far as they are an index of the food adapted to them, it is plain that man is frugivorous. But the same conclusion is further supported by an examination of the digestive apparatus.

In carnivorous species, the intestine through which the food passes is generally short, its length not exceeding three or four times that of the body, while in the herbivorous species it is usually ten or twelve, and sometimes (as in the sheep, for example) twenty-eight times the length of the body. In accordance with this principle, we find that the human intestine, like the teeth, is suited to vegetable aliment, having a length bearing a proportion to that of the body, which is analogous to the internal structure of other frugivorous species.

24. How then, it may be asked, has it happened that man, instead of being exclusively frugivorous, is, in fact, omnivorous, nourishing himself indifferently with vegetable and animal aliment? The answer is obviously, that he cannot be nourished by animal aliment, unless it be previously prepared by fire. In a word, flesh, to be fit for human food, must be cooked.

25. One of the physical peculiarities which distinguishes man from other members of the animal kingdom, is the facility with which his organisation adapts itself to differences of climate, and this is one of the marks which appear to confirm his destiny to rule over the whole surface of the globe. Placed originally by his Maker in a single region, his race has multiplied and diffused

itself, manifesting a constant tendency to emigration, and being deterred neither by the rigours of the pole, nor the scorching sun of the tropics, it has overspread the globe. According to statistical estimates, which are considered as exact as such calculations can be, it was ascertained that, at the epoch of 1840, the total population of the globe amounted to about 737,000000, which were distributed in the following proportions, the number to every square league, taking the length of a league as the 25th part of a degree, being given in the second column :—

	Population.	Per Sq. League
Europe	227,700000	472
Asia	390,000000	184
Africa	60,000000	40
America	39,000000	20
Oceania, including the isles of the Pacific Ocean, &c.	20,000000	37

The density of the population, indicated in the last column, depends more on civilisation and wealth than on climate. Thus, it is computed that the number of inhabitants per square league in the different states of Europe, are as follows :—

United Kingdom	1480
France	1200
Prussia	895
Russia	202

26. Having taken this rapid view of the physical organisation and condition of the human race, let us trace the progress of the animal Man from the cradle to the grave.

27. In general, man comes into the world singly, or one at a birth. In certain exceptional cases, two are born, and called twins. The cases in which three or more at a birth are produced are so extremely rare as not to have received in any language, that we are aware of, a distinct appellation.

28. It appears by statistical returns, that, upon an average, one case of twins occurs in 90 births; and that three at a birth has occurred only once in 30000 cases.

29. Another circumstance, in which the human race is distinguished from inferior animals, is the independence of the phenomenon of birth on the season of the year. Animals generally produce their young at that season which is most favourable for their development. Children are born at all seasons. Nevertheless, in comparing the number of births with the course of the

seasons, it is found to be variable, and that its variation has a marked and well-ascertained relation to the course of the seasons. It is found generally in the temperate climates, that births are more numerous in the three winter, and least so in the three summer months. In approaching the colder climates, the epochs of the maximum and minimum numbers are later, and in approaching the warmer climates earlier.

30. The number of children which come into the world is not equally shared between the sexes, the male always predominating.

This fact has been established in all countries where statistical registers have been kept; and it is remarkable, that although the numerical proportion between the sexes is subject to some variation from year to year, its mean amount in each country is nearly invariable, though different in one country as compared with another. Thus, on comparing the numbers of male and female children baptised in England and Wales during the first half of the present century, it is found that the number of males invariably exceeded the number of females in a proportion, varying from year to year, from 25 to 50 per 1000; the mean result taken for the whole period showing, that for every thousand girls born, there were one thousand and forty boys.

In France, according to returns extended over 36 years, terminating in 1852, it appears, that for every thousand girls there were one thousand and sixty-one boys born. Thus the preponderance of male births in France exceeds that in England in the proportion of a little more than 6 to 4.

By returns obtained from other countries where accurate statistics are kept, it has been found that the preponderance of male births is intermediate between those of England and France, the number of males being 1050 for every 1000 females.

31. A very remarkable fact, indicating some undiscovered physiological law, has been developed by the analysis of the returns of the registrations of births obtained from France and other countries where the most exact statistical records are kept. It has been found generally, that in that particular class of children, to which foundlings for the most part belong, the preponderance of male births is considerably less than in the case of marriage-born children. Such a circumstance would naturally enough be regarded as merely accidental, if it were not found to prevail invariably, at all epochs in all countries where registers are kept with sufficient precision to test the fact, and in all provinces of the same country. Thus, for example, while in France there are 1060 marriage-born boys for 1000 girls, there are only 1040 boys of the other class for the same number of girls; and

this proportion has been found to be maintained from year to year, and equally in different departments.

From a comparison of the births in different departments of France, north and south, it has been found that the proportion of the sexes born is not affected by climate.

32. It must not be supposed, however, that this ratio between the sexes continues through life. The chances of life being more favourable on the whole to females than to males, the excess given to the latter at birth is equalised before the middle age; and at more advanced ages, the balance turns the other way, and the females predominate.

33. In coming into the world, the infant can open the eyes, but physiologists consider that it has no sense of vision, and that it is only at the end of some weeks that it begins to be sensible of visible objects. After this, it directs its looks to objects which are most brilliantly illuminated, or which are characterised by the most vivid colours. It then, by slow degrees, begins to distinguish objects around it, but it has been ascertained that a considerable time elapses before it has any idea of distances or magnitudes.

Indeed, this is quite consistent with effects which have been found to result from surgical operations in which sight has been restored to persons blind from infancy. In such cases, it has been stated that the subject of the operation, when first enabled to see, imagined that all the objects which he beheld were in immediate contact with his eyes, and had not the least idea of their relative distances, nor any other notions of their magnitudes or forms than such as were afforded by their profiles. Every object, in short, appeared as a coloured silhouette in close contiguity with the organs of vision.

34. The other organs equally undergo a progressive improvement by exercise. During five or six months the infant makes no other vocal sound than inarticulate cries. It begins gradually to be sensible of pleasurable emotions from the contemplation of external objects, which are expressed by its smiles. The cries gradually assume the tone and character of the voice, and are accompanied by incipient efforts at articulation, and towards the close of the first year the more simple monosyllabic words are pronounced.

35. The bones, which at the time of birth consist to a great extent of cartilage or gristle, and have no strength sufficient to support the body, receive, in the process of nutrition, a gradual accession of the earthy constituent called the phosphate of lime, which gives them hardness. Contemporaneously with this increase of strength in the bones, there is a proportionate growth

and increase of strength in the muscles which move them, and about the close of the first year this strength bears such a relation to the weight of the body, that the child is enabled to support itself on its legs, and by gradual practice acquires the ability to walk.

36. It is generally assumed that man is distinguished from the inferior animals by the substitution of reason for instinct, and in this way it is explained how the young of other animals manifest at the moment of birth the possession of powers and faculties, which, in the case of the young of the human race, are acquired only by long practice and slow degrees. It is therefore contended, that while the young of the lower animals are governed exclusively by instinct, the young of man is as exclusively governed by reason, the conclusions of which are based upon experience. The acts prompted by instinct are performed as perfectly at first as at last, and undergo no progressive improvement; while, on the contrary, the dictates of reason being based upon experience, cannot be issued by the mind until the results of that experience, which are their only data, have been developed. It has, therefore, been argued, that the helplessness of the infant, and the slow and gradual progress of the exercise of its senses and members, must be explained by the total absence of instinct. This conclusion, however, it seems cannot be admitted in its absolute sense, and observation and experience show that it requires considerable qualification. Many eminent physiologists impugn it, and Sir Charles Bell has even expressed a doubt whether the actions of the body, if not first instinctive or prompted by innate sensibilities, would ever be exercised under the exclusive influence of reason. The sensibilities and motions of the lips and tongue are, according to him, perfect at birth; and the fear of falling is manifested by the infant long before the results of experience can suggest it. The hand, destined to become the instrument not only for the improvement of the senses, but for the development of the mental faculties, is absolutely powerless in the infant. Although capable of expressing pain, it is unconscious of the part injured. But the lips and tongue immediately betray their sensibility. Later, the infant puts its fingers into its mouth to suck them, and so soon as they are capable of grasping, whatever they lay hold of is carried to the mouth.

"The first office of the hand, then, is to exercise the sensibility of the mouth, and the infant as certainly questions the reality of things by that test, as does the dog by its acute sense of smelling. In the infant the sense of the lips and tongue is resigned in favour of that of vision, only when the exercise of the eye has improved

and offers greater attraction. The hand acquires the sense of touch very slowly, and many ineffectual efforts may be observed in the arms and fingers of the child, before it can estimate the direction or distance of objects. Gradually the length of the arm, and the extent of its motions, become the measure of distance, of form, of relation, and perhaps of time.

37. "Next in importance to the sensibility of the mouth, we may consider that sense which is early exhibited in the infant, the terror of falling.

"The nurse will tell us that the infant lies composed in her arms, while she carries it upstairs, but that it is agitated when she carries it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest when it is raised, but in descending it will struggle and make efforts. Here is the indication of a sense, an innate feeling of danger, and we may perceive its influence when the child first attempts to stand or run. When set upon its feet, the nurse's arms forming a hoop around it, without touching it, the child slowly learns to balance itself and stand; but under a considerable apprehension. It will only try to stand at such a distance from the nurse's knee, that if it should fall, it can throw itself for protection into her lap. In these, its first attempts to use its muscular frame, it is directed by a fear which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children are, therefore, cowardly by instinct; they show an apprehension of falling, and we may trace the gradual efforts which they make under the guidance of this sense of danger to perfect the muscular sense. We thus perceive how instinct and reason are combined in early infancy; how necessary the first is to existence; how it soon becomes subservient to reason, and how it eventually yields to the progress of reason, until obscured so much that we can hardly discern its influence." *

38. At the moment of birth, twenty teeth already formed and ossified are deposited, ten in the lower and ten in the upper jaw, but are completely covered by the gums. The mouth is thus constituted exclusively for application to the mother's breast and for the suction of milk from it, and the stomach and intestines are organised in accordance with this for the due digestion of that aliment. The constituents of the healthy milk of woman are the same as those of the body of the child, and enter into its composition in a corresponding proportion. By the process of digestion, they are distributed among the several organs of the child's body,

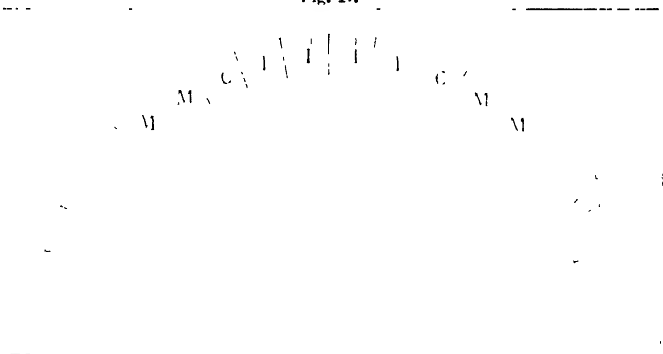
* Bell, On the Hand, p. 233.

each passing to that for whose sustenance and growth it is fitted. At the age of from six to ten months, the first teeth penetrate through the gum, and towards the end of the second year the entire number have appeared. These twenty teeth are classified according to their peculiar forms, as incisors, canines, and molars. The incisors are chiselled, the canines pointed, and the molars presenting a broad and rough summit. When the mouth is closed the molars of the upper jaw corresponding in position with those of the lower, rest upon them. But the lower incisors and canines lie within the edges of the upper ones. In each of the jaws, there is, however, space for sixteen teeth, and consequently three places at each side remain unoccupied.

The relative arrangement of this set of teeth is shown in fig. 17, where the incisors are indicated by I; the canines by C, and the molars by M; the unoccupied spaces being marked ″

The first teeth which break through the jaw, are the middle

Fig. 17.



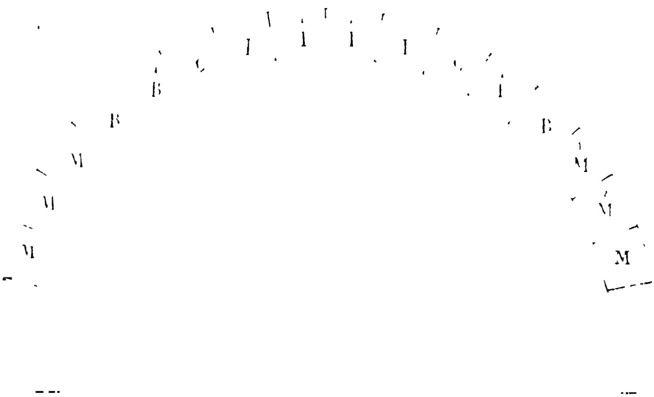
incisors I^1 I^1; these are succeeded in regular succession by the lateral incisors I^2 I^2, the canines C C, and the molars M^1 M^1 and M^2 M^2.

39. This first set of teeth are called the milk teeth, because of their emergence from the gums at the time when the aliment of the child is changed from the milk of the mother to other forms of food. Towards the seventh year, these teeth begin to be pushed out of the jaw by another set which have been growing beneath them. The incisors and canines are pushed out by another set perfectly similar in form and name, which take their places. The molars are in like manner extruded by four teeth in each jaw called *bicuspids*, having an intermediate character between incisors and molars.

Later still, four molars issue from the gum in each jaw, two at each side, occupying the first two of the three vacant places marked ″ in fig. 17, and at a still more advanced age, two other molars issue from each jaw, filling the last vacant place marked ″ in the fig. 17.

Thus, a set of sixteen permanent teeth is established in each jaw (fig. 18). The last four molars, which emerge at a period of

Fig. 18.



life much later than the others, have been for that reason vulgarly called wisdom teeth.

40. The periods of the successive emergence of the permanent teeth are, according to Cartwright, as follows :—

	AGE.
Middle incisors of lower jaw (I^1), and first molars (M^1)	5 to 7
Middle incisors of upper jaw	6 to 8
Lateral incisors (I^2)	7 to 9
First bicuspids (B^1)	8 to 10
Canines (C)	9 to 12
Second bicuspids (B^2)	10 to 12
Second molars (M^2)	12 to 14
Third molars (M^3) (wisdom teeth)	17 to 25

41. The mean height of man is about 5 feet 6 inches, but is subject to great variation, not only in the case of individual compared with individual, but nation with nation, and race with race. Some of the savage tribes of Patagonia, and the inhabitants of the Navigator and Caribbean islands, are remarkable for their elevated stature, their average height varying from 6 feet to 6 feet 3 inches.

On the contrary, the Esquimaux and Bushmen have an average height not exceeding 4 feet 3 inches.

42. If, instead of comparing people with people, individual be compared with individual, still greater departures from the average standard are found. Thus, we have seen giants which have attained the enormous height of 9 feet 6 inches, and, on the other hand, dwarfs whose height did not exceed 2 feet.

43. Among persons of average height, women are about a sixteenth less tall than men; but among people whose average height is less than the common standard, such as the Esquimaux and Bushmen, there is less inequality between the sexes; while in those of greater average height, such as the Patagonians, the inequality is greater. In fact the sexual inequality appears to vary nearly in the ratio of the mean stature.

The inequalities of mean stature observed in comparing people with people, depend partly upon race, or partly on the physical conditions with which they are surrounded.

44. The influence of race is more especially apparent when different people, inhabiting the same country, with similar manners, and subject to like climatological influences, are compared together. In Patagonia, for example, where certain nomadic tribes of very elevated stature prevail, there are others whose stature has about the ordinary standard, and at a little distance in the Tierra del Fuego, people of low stature prevail. The people of greatest mean stature are found chiefly in the southern hemisphere, either on the South American continent, or in the several archipelagos of the Southern Ocean.

45. Although people of low average stature are found within the tropics, and in places near the Cape of Good Hope, where the climate is sufficiently temperate, it cannot be doubted that a rigorous climate is unfavourable to the development of the human form, for in high latitudes in both hemispheres the inhabitants are invariably characterised by diminutive stature.

Moderate cold, on the contrary, is favourable to the corporeal development. In France and other parts of Europe, where the climate is mild, the average stature is less than in the colder parts of Europe, such as Sweden, Finland, and even Saxony and the Ukraine.

46. Temperature, however, exercises on the whole less influence upon bodily development than the general hygienic conditions of a people, and it may be received as a general principle that the mean stature will be so much the more elevated, and the complete growth sooner accomplished, other things being the same, as the country inhabited by a people is more fertile and abundant, and the sufferings and privations sustained during youth less consider-

able. Innumerable proofs of this truth may be found by comparing nation with nation. But it may be rendered still more strikingly apparent by comparing together the inhabitants of different provinces of the same country, or even those of different divisions of a large city.

47. It is well known that, by the laws of France, the army is recruited by conscription, in carrying out which means are incidentally supplied of ascertaining with great precision the sanitary condition and bodily development of the population. The capital of that country, containing upwards of a million of inhabitants, is distributed into quarters, called arrondissements, which differ one from another in relation to wealth or poverty, even more than do the various quarters of London. Thus while in the north-western arrondissements misery and want are rare, in some others, such as the 6th, the 11th, and the 12th, they prevail to a great extent. In the former, 45 in every 100 conscripts are found unfit for military service, chiefly because of insufficient stature, and the remaining 55 have an average height 5 feet 6$\frac{1}{2}$ inches, while in the latter quarters, where poverty is more prevalent, 52 in a 100 are rejected, and the remaining 48 have an average height of only 5 feet 6 inches.

48. Statistical returns sufficiently exact and regular to indicate the average progressive growth of the human body, though rare, are not unattainable. In Belgium, for example, where the average stature is somewhat greater than in France, it has been found that the average height of new-born infants is 19$\frac{1}{5}$ inches, and at the end of the first year it is increased to 27$\frac{1}{2}$ inches.

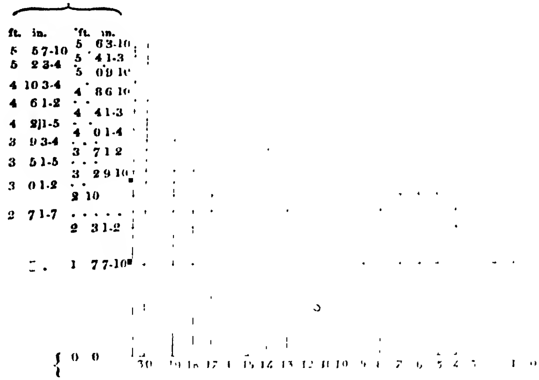
In the second year the growth is less rapid, and in every succeeding year becomes less and less so, until the full growth has been attained. The annexed diagram, however, fig. 19, will convey a more exact notion of the mean progressive growth than could any mere numerical statements. It is due to M. Quetelet, to whose physical and statistical researches science is otherwise so largely indebted. The successive years in the age of an individual, from the moment of birth to the age of thirty, are indicated in the horizontal line, and the corresponding average heights in the vertical column.

It appears, therefore, that at the moment of birth the infant has a stature equal to about 2-7ths, and at three years old, about half of its ultimate height.

At the moment of birth, the average height of boys exceeds that of girls by about the 20th of an inch, and this difference increases with their growth. Nevertheless, the results obtained by M. Quetelet must be received merely as first approximations; the observations and inductions necessary to establish general and certain laws being much more numerous than any which statistical records have yet

supplied. It may, however, be assumed that in extreme climates, whether hot or cold, the body arrives at its full height sooner

Fig 19.



than in temperate climates; in towns sooner than in the country, and in plains sooner than in mountainous districts.

49. The development of the body in bulk is slower than its growth in height. A new-born infant has upon an average about a twentieth of the weight which it will acquire upon attaining its greatest development, which takes place in general for men at 40 and for women at 50.

During the first year after birth, the increment of weight is about $\frac{1}{10}$ of all that it will receive during its subsequent existence; and the increase of weight received from the 15th to the 20th year is even greater than that which is acquired in the first five years.

50. On arriving nearly at the limit of his stature, the male passing from youth to manhood undergoes several organic changes. His bones having acquired a larger proportion of the earthy constituent, have increased strength, his muscles are more developed and powerful. His voice losing the feminine pitch which characterises boyhood, becomes almost suddenly much more grave, and his beard is rapidly developed.

The corresponding changes in the female organism are manifested somewhat earlier, and show themselves by external forms familiar to every eye. The chest becomes enlarged, the shoulders expanded, and the pelvis acquires greater width, and the forms of womanhood become conspicuously visible. In temperate climates these changes are manifested at from 14 to 16 years of age. In warm climates they take place at from 10 to 11, and in colder countries are postponed to 17 or 18.

51. Growth produces in the species a somewhat remarkable change in the mechanical qualities of the bones. This important part of our organism consists of three constituents, fibre, cartilage, and the earthy matter already mentioned called *phosphate of lime* From the fibre they derive their toughness; from the cartilage their elasticity, and from the lime their hardness and firmness. Nothing can be more admirable in the economy of our body than the manner in which the proportion of these constituents adapts itself to the habitudes of age. The helpless infant, exposed by a thousand incidents to external shocks, has bones, the chief constituents of which being gristly and cartilaginous, are yielding and elastic, and incur little danger of fracture. Those of the youth, whose augmented weight and increased activity demand greater strength, have a larger proportion of the calcareous and fibrous elements, but still enough of the cartilaginous to confer upon the solid framework of his body the greatest firmness, toughness, and elasticity. As age advances, prudence and tranquil habits increasing, as well as the weight which the bones have to sustain, the proportion of the calcareous constituent increases, giving the requisite hardness and strength, but diminishing the toughness and elasticity.

While the bones thus change their mechanical qualities as age advances, they diminish in number, the frame consequently having fewer joints and less flexibility. The bones of a child, whose habits require greater bodily pliability, are more numerous than those of an adult, several of the articulations becoming ossified between infancy and maturity. In like manner, the bones at maturity are more numerous than in advanced age, the same progressive ossification of the joints being continued.

It has been ascertained by anatomists that, on attaining the adult state, the number of bones constituting the framework of the human body is 198; of which 52 belong to the trunk, 22 to the head, 64 to the arms, and 60 to the legs.

52. This wonderful solid structure is moved by a mechanical apparatus, consisting of about 400 muscles, each of which is attached at its extremities to two points of the body, more or less distant from each other, which it has the power of drawing towards each other by a contractile property peculiar to it. These muscles, however, being passive pieces of mechanism, are moved as already mentioned by the nerves, while the nerves themselves are moved by the will, and here the material mechanism ends, and the intellectual or the spiritual begins.

As age advances, the organs lose their suppleness and elasticity; the weight of the body undergoes a sensible diminution; the powers of digestion and assimilation are gradually impaired; the

vital flame decreases in splendour, and flickering in its socket, at length, and with apparent reluctance, goes out.

53. Death, however, by the mere effect of age, is extremely rare, being in most cases produced by accidental causes, to which imprudence exposes us. Innumerable examples prove to how great an extent life may be prolonged beyond its average limits. Without citing the extraordinary examples of longevity found in the records of the first ages of the world, supplied by the Sacred Scriptures, examples sufficiently numerous may be produced nearly from our own times.

One of the most remarkable examples of longevity which modern times have presented, is that of a poor fisherman, an inhabitant of Yorkshire, by name Henry Jenkins, who died in 1670, at the age of 157. Peculiar circumstances have incidentally supplied evidence of the great ages of this individual, and two of his sons. He was summoned on a certain occasion before a court of justice, to give evidence of a fact which had occurred 140 years previously; and he appeared before the tribunal attended by his two sons, the younger of whom had attained the age of 100, and the elder that of 102. Various other examples are cited of nearly equal longevity, but for the most part they refer to times or places at which the registers of births and deaths were not kept with such regularity as to entitle the statement to confidence. It is, however, extremely rare to find an individual who has exceeded the age of 100. According to the bills of mortality of the City of London, it appears that, of 47000 deaths which took place in the ten years ending in 1762, there were only 15 centenarians. In France, during the three years ending with 1840, there were 2,434993 deaths, of which 439 were reputed centenarians, which would give a proportion of about 1 in 5500.

54. One of the saddest spectacles presented by the analysis of the general progress and termination of human life, is the vast proportion of our race which are swept away in the first years of their existence; a circumstance which can only be explained by the care which infancy requires, and the inability of the poor and labouring classes to bestow it. It appears, from the statistical records so accurately kept in France, that of every 100 children born, 24 die in the first year; 33 in the first two years; 40 in the first four years; and 50 in the first twenty years. Thus it appears that only half the children born in France survive for the purpose of the continuance of the race. According to similar records published in England, it appears that 40 in 100 die in the first 5 years, and 11 more between that and 20; so that the survivors at 20 are something less than half the number born.

Fig. 22.—ETHIOPIAN.

COMMON THINGS.

MAN.

CHAPTER III.

55. Average duration of life.—56. In England and France.—57. Great mortality of foundlings.—58. Average number of children per marriage.—59. Influences which produce permanent changes in man.—60. Indications of a common origin for the human race.—61. Naturalists in this verify the Hebrew Scriptures.—62. The five races of men.—63. The Caucasian variety.—64. The Mongol.—65. The Malay.—66. The Ethiopian.—67. The American.—68. The relation of languages.—69. The limits of physiological and psychological speculation.—70. Man material and intellectual.—71. Connection between the physical and the intellectual.—72. Personal identity.—73. Analysis of the constituents of the human body.—74. The absurd consequences of materialism.—75. Further difficulties from the question of personal identity.—76. The body said to change altogether once a month.—77. The intellectual part however suffers no change—materialism disproved.—78. Regularity of moral and intellectual phenomena.—79. Difference between them and physical phenomena.—80. Freedom of will does not prevent these phenomena, considered collectively, from observing general laws.—81. Example of statistical phenomena.—82. Frequency of marriages.—83. Constant proportion of unequal marriages.—84. Proportion of illegitimate children.—85. Prevalence of crime, and proportion of acquittals.—86. Acts of forgetfulness—number of unaddressed letters posted.—87. General conclusion.

55. The mean duration of life in England and Wales during the 40 years ending with the year 1840, varied from thirty-one to thirty-seven years, the variation, however, not being regular, and its mean value being thirty-four years.

56. A similar calculation applied to the population returns in France during the 36 years ending with 1852, showed a progressive increase of the mean duration of life. During the first eight years, ending with 1824, the mean length of life was 31·8 years, and during the last eight years, ending with 1852, it was 36·7. Its mean value for the whole interval of 36 years being 34·2 years, the same as in England.

Now, it will not fail to strike every one that this term of life is greatly below that which would result from general observation, independently of all statistical results. A person dying at thirty-four would be lamented by all as one taken away prematurely in the prime of life. This discrepancy between the results of statistics and common observation admits of easy explanation. The estimate made by common observation is tacitly based upon a rough average taken of the ages at which those die who have already entered upon the scene of life, and have been recognised by all as members of the human family. The more exact calculations of statistics include rigorously all that are born into the world, of whom so large a proportion die in their first year; and as we have seen, not less than 4-10ths in that term of infancy, during which they can scarcely be said to be recognised by common observation as forming part of the population. To render the results of the computation of the absolute duration of life applicable to the 6-10ths which arrive at the adult state, it will only be necessary to augment the computed duration of life in the ratio of 6 to 10. If, therefore, as has been shown, the actual mean duration of life in England and France be 34 years, the mean length of life of those who survive their infancy will be 56 years, which, it is evident, is in complete accordance with common observation.

57. How much the preservation of life during infancy is dependent on parental care, is rendered conspicuously apparent by the melancholy fact established by the statistical returns, that 80 per cent., or four in every five of the children abandoned in France as foundlings, die in their first year.

58. The number of children resulting from each marriage is found by the simple method of comparing the total number of annual legitimate births with the total number of annual marriages. By this process, it appears that the mean number of children to every two marriages in France is seven, and in England eight, these mean results being subject to a very slight variation from year to year.

59. The human race, as is well known, consists of a considerable number of varieties, differing one from another in personal appearance, character, language, in their average degree of

moral and intellectual powers, and in their geographical distribution. Those whose observations have been mainly confined to the extremes of form and colour, and who have not reflected on the wonderful changes to which all organised beings are subject by various external physical causes,—changes which, when once superinduced, are transmitted, not only in man, but in inferior animals, and even in plants, through the series resulting from reproduction,—have viewed the differences observed among the members of the human family, not as characteristics of so many varieties of a single species, but as marks distinguishing different species of the same genus. We have, however, the authority of the greatest living observer of nature, as developed in the animal kingdom, in opposition to this cheerless doctrine.

60. "The permanence of certain types, in the midst of most opposite influences," says Humboldt, "especially of climate, appeared to favour this view, notwithstanding the shortness of the time to which the historical evidence applied; but in my opinion, more powerful reasons lend their weight to the other side of the question, and corroborate the unity of the human race. I refer to the many intermediate gradations of the tint of the skin, and the form of the skull, which have been made known to us, by the rapid progress of geographical science in modern times, to the analogies derived from the history of varieties in animals, both domesticated and wild, and to the positive observations collected respecting the limits of fecundity in hybrids. The greater part of the supposed contrasts, to which so much weight was formerly assigned, have disappeared before the laborious investigations of Tiedemann on the brain of negroes and of Europeans, and the anatomical researches of Vrolik and Weber, on the form of the pelvis. When we take a general view of the dark-coloured African nations, on which the work of Prichard has thrown so much light, and when we compare them with the natives of the Australasian Islands, and with the Papuas and Alfourous, we see that a black tint of skin, woolly hair, and negro features, are by no means invariably associated. So long as the western nations were acquainted with only a small part of the earth's surface, partial views almost necessarily prevailed. Tropical heat, and a black colour of the skin, appeared inseparable. 'The Ethiopians,' said the ancient tragic poet, Theodectes of Phaselis, 'by the near approach of the Sun-God in his course, have their bodies coloured with a dark sooty lustre, and their hair curled and crisped by his parching rays.' The campaigns of Alexander, in which so many subjects connected with physical geography were originally brought into notice, occasioned the first

discussion on the problematical influence of climate on nations and races." *

61. Thus it appears that according to the principles admitted by the most eminent physiologists and naturalists, whether assenting or not to the doctrines of Christianity, there is nothing in the natural differences observable between different parts of the human race distributed over the globe, which is incompatible with that part of the narrative of the origin of mankind, consigned to the Hebrew Scriptures, which traces the whole human race to a single pair and constitutes them therefore as members of a common family.

62. Naturalists and physical geographers have distributed by various classifications these varieties of men, and have generally given them the somewhat vague and improper name of races. Thus Blumenbach classifies them into five races, called the Caucasian, the Mongolian, the American, the Ethiopian, and the Malay. Some authorities reduce this number to four, regarding the Malay merely as a variety of the Ethiopian.

Dr. Prichard, on the other hand, classifies the human family into seven races, which he calls.—

The Iraunian,
The Turanian,
The American,
The Hottentots and Bushmen,
The Negroes,
The Papuas,
And the Alfourous.

This division is objected to by Humboldt, and does not appear to have obtained general acceptation.

63. The Caucasian race (fig. 20), p. 49, in which the population of Europe is included, is distinguished by the beauty of the oval form of the head and countenance; by the large facial angle, amounting to about 90°; by the consequent upright forehead; the horizontal direction of the eyes; the absence of all projection of the cheeks; fine smooth hair; and the fair tint of the skin. They are, however, still more remarkable for the high degree of perfection to which their moral and intellectual faculties speedily attain; a quality which has rendered them the most civilised people of the globe. They occupy all Europe, western Asia as far as the Ganges, and the northern part of Africa. They have derived their name of Caucasian from the supposition that they came originally from the country north of Mount Caucasus, lying between the Caspian and the Black Sea. Although generally fair, they include various

* Cosmos, vol. i. p. 352, translation.

shades, from the extreme fairness of the red-haired northern to the swarthy inhabitants of certain parts of the Spanish peninsula and of North Africa.

64. The Mongol variety (fig. 21) p. 65, differs in several respects from the Caucasian. Their face is flat; their forehead low, oblique, and angular; their cheek-bones salient; their eyes small, and set obliquely; the chin slightly prominent; the beard sparse; the hair long, straight, and black; and the complexion a yellow or sallow olive.

The languages spoken by the Mongol variety are extremely different from those of the Caucasian, being for the most part monosyllabic. This variety is spread eastwards over the countries occupied chiefly by the Caucasian races. They are encountered in the great desert of Central Asia, where the Kalmucks and other Mongol tribes are still nomadic. Almost the whole population of the eastern part of Siberia is Mongo ; but the nation which forms the most remarkable part of this race is the Chinese, whose vast empire was, of all parts of the world, the first civilised; although the exclusive spirit of their laws and customs, which has raised a barrier between them and the rest of mankind, has kept them stationary for ages.

65. The Malay variety occupies the islands of the Indian Archipelago, New Zealand, Chatham Islands, the Society Group, the Philippines and Formosa, and several of the Polynesian Islands. They are dark; have lank, coarse, and black hair; flat faces; and eyes obliquely set. In their moral and social qualities, they vary extremely in different localities; some being active and ingenious, mild and gentle, and considerably advanced in the arts of life; while others are ferocious, vindictive, daring, and predatory. To this variety are generally referred a considerable part of the population of the extreme north of Europe, such as the Greenlanders, Laplanders, Samoides, and Esquimaux.

66. The Ethiopian variety, or Negro (fig. 22), is characterised by his compressed skull, small facial angle, flat nose, salient jaws, thick lips, woolly and crisped hair, and black skin. The habitation of this variety is south of Mount Atlas, and is spread over all the remainder of the African continent, Madagascar, Australia, Mindanao, Gillolo, the islands of Borneo, Sumbawa, Timor, and New Ireland. It consists of several sub-varieties, such, for example, as the Mozembics, the Bushmen, and the Hottentots.

67. The American variety is generally characterised by a copper-coloured skin, sparse beard, and long black hair. They differ extremely, however, one from another; some tribes manifesting a close analogy to the Mongols, others approaching close to the external characters of Europeans; the nose is generally

prominent, like the European; the eyes being large, regular, and disclosed by widely opened lids.

68. The question of the descent of all these varieties from a common origin, is closely connected with the analysis of languages. Nothing affords a more convincing proof of identity of origin than the discovery of similar forms of expression and terms, having like roots in the tongues spoken by distant people. "But here," observes Humboldt, "as in all fields of ideal speculation, there are many illusions to be guarded against, as well as a rich prize to be attained. Positive ethnographical studies, supported by profound historical knowledge, teach us that a great degree of caution is required in these investigations concerning nations, and the language spoken by them at particular epochs. Subjection to a foreign yoke, long association, the influence of a foreign religion, a mixture of races, even when comprising only a small number of the more powerful and more civilised emigrating race, have produced in both continents similar recurring phenomena, viz., in one and the same race two or more entirely different families of languages, and in nations differing widely in origin, idioms belonging to the same linguistic stock. Great Asiatic conquerors have been most powerfully instrumental in the production of striking phenomena of this nature.

"But language is an integral part of the natural history of the human mind; and, notwithstanding the freedom with which the mind pursues perseveringly, in happy independence, its self-chosen direction under the most different physical conditions,—notwithstanding the strong tendency of this freedom to withdraw the spiritual and intellectual part of man's being from the power of terrestrial influences, yet is the disenthralment never completely achieved. There ever remains a trace of the impression which the natural disposition has received from climate, from the clear azure of the heavens, or from the less serene aspect of a vapour-loaded atmosphere. Such influences have their place among those thousand subtle and evanescent links in the electric chain of thought, from whence, as from the perfume of a tender flower, language derives its richness and its grace."

By maintaining the unity of the human species, we at the same time repel the cheerless assumption of superior and inferior races of men. There are families of nations more readily susceptible of culture, more highly civilised, more ennobled by mental cultivation than others, but not in themselves more noble. All are alike designed for freedom; for that freedom which in ruder conditions of society belongs to individuals only, but where states are formed, and political institutions enjoyed, belongs of right to the whole community. "If," says Wilhelm von Humboldt,

"we would point to an idea which all history throughout its course discloses as ever establishing more firmly and extending more widely its salutary empire,—if there is one idea which contributes more than any other to the often-contested, but still more often misunderstood, perfectibility of the whole human species,—it is the idea of our common humanity tending to remove the hostile barriers which prejudices and partial views of every kind have raised between men; and to cause all mankind, without distinction of religion, nation, or colour, to be regarded as one great fraternity aspiring towards one common end, the free development of their moral faculties. This is the ultimate and highest object of society; it is also the direction implanted in man's nature, leading towards the indefinite expansion of his inner being. He regards the earth and the starry heavens as inwardly his own, given to him for the exercise of his intellectual and physical activity. The child longs to pass the hills or the waters which surround his native dwelling, and his wish indulged, as the bent tree springs back to its first form of growth, he longs to return to the home which he had left; for by a double aspiration after the unknown future and the unforgotten past, after that which he desires and that which he has lost, man is preserved by a beautiful and touching instinct from exclusive attachment to that which is present. Deeply rooted in man's most innate nature, as well as commanded by his highest tendencies, the full recognition of the bond of humanity, of the community of the whole human race with the sentiments and sympathies which spring therefrom, becomes a leading principle in the history of man." *

69. When we come to trace the conduct of man as an individual member of the social body and to connect it with his physical organisation, we tread upon the interesting ground which forms the confines between the legitimate territories of the physiologist and psychologist, between the provinces of the natural philosopher and the theologian; and however closely our vocation and habitudes have attached us to the contemplation and investigation of mere physical laws, we cannot forbear to throw a passing glance into the spiritual world.

70. Man's nature, according to the admission of all, is a compound of the material and the intellectual. According to some, to whom, on that account, the name of *materialists* has been given, the intellectual is a mere function or property of the material part of our nature. According to others, the intellectual is a function of a spiritual essence, which is independent of our material organi-

* Cosmos, translation, p. 354.

sation, though inseparably connected with it during human life. The name of *spiritualists* has, accordingly, been given by contradistinction to the latter.

71. Our nature being thus compound, let us see how far we can trace the connection between its mere physical part and the thinking and intelligent principle which abides in it.

72. There is a principle called in metaphysics personal identity, which consists in the internal consciousness by which each individual knows his past existence, so as to be able, with the greatest certainty of which the judgment of our minds is susceptible, to identify himself existing at any given moment with himself, existing at any former time and place. Nothing in human judgment can exceed the clear certitude which attends this consciousness. The Duke of Wellington, on the eve of his death at Walmer, had an assured certainty that he was himself the same individual intelligent thinking being, who, on the 18th of June, 1815, commanded at Waterloo the allied armies. Now to what, let us ask, did this intense conviction and consciousness of identity apply? What was there in common between the individuals who died at Walmer and who commanded at Waterloo? The reply to this question will require that we shall recur for a moment to our physical organisation.

73. The human body consists of bones, flesh and blood, each of which is, however, itself a compound substance, and the whole is impregnated in a large proportion with water. Thus, the quantity of blood in an average body is 20 lbs., of which 15 lbs. are water, the other 5 lbs. consisting of those material constituents which are necessary for the supply of the growth or the repair of the body. The flesh, commonly so called, is pervaded by blood-vessels, and therefore, strictly speaking, is a combination of flesh and blood. In like manner, the bones are pervaded to their very centres by innumerable blood-vessels, so minute as to be microscopic, by which their growth is supplied and their waste repaired. Taking, however, the terms flesh, blood, and bone in their proper meaning, excluding from each the water with which it is impregnated, and excluding from the flesh and bone the blood which pervades them respectively, the material constituents of an average human body may be thus stated:—

Bone	14 lbs.
Flesh and blood	24
Water	116

The bone, when submitted to analysis, is shown to consist of certain earthy matter, the chief part of which is lime and a substance called *gelatine;* this gelatine itself being a compound,

one half of which is pure charcoal, called by chemists *carbon*, and the other a combination of the gases which constitute common air and water. From this analysis it follows that, in round numbers, the 14 lbs. of bone which enter into the composition of the human body, omitting minute fractions and insignificant quantities, consist of 10 lbs. of lime, 2 lbs. of charcoal, combined with 2 lbs. weight of the gases just mentioned.

A similar analysis of flesh and blood shows that they consist, in nearly equal parts, of charcoal and the same gases, so that the 24 lbs. weight of these substances which enter into the composition of an average body, are resolved into 12 lbs. of charcoal, combined with an equal weight of the gases already mentioned.

Thus, in fine, the ultimate materials of the average human body, are 14 lbs. of charcoal and 10 lbs. of lime, impregnated with 116 lbs. of water, and 14 lbs. weight of the gases which form air and water, that is, *oxygen*, *nitrogen*, and *hydrogen*.

74. Now those who think that the intellectual principle residing in the human body is nothing more than a quality or a property arising from the matter composing it, must be able to imagine how 14 lbs. of charcoal, 10 lbs. of lime, and 116 lbs. of water can be so mixed up with 14 lbs. of air as to make a material thing—machine let us call it—which can feel, think, judge, remember, and reason. Let us try to imagine, for example, the possibility of such a mass of charcoal, lime, and water discovering the existence, position, and motion of the planet Neptune before it was ever seen; of ascertaining the periodicity of the planetary inequalities, countless ages before many of these inequalities had passed through one of their periods; of inventing the printing press, the ship, the steam-engine, and the electric telegraph; of composing "Paradise Lost;" of producing the Transfiguration and the Antinous, or of designing the Parthenon!

But it will be answered, that the power of intelligence is ascribed not to the mere inert materials of the human body, but to their organisation. What, then, is organisation? Let us not be misled by a long and learned word. Organisation is, and can be, but some particular way of arranging the parts of which any thing is composed. Thus, a given number and weight of stones may be arranged in a thousand different ways, so as to compose as many different structures, but each such structure is still a mere mass of stone. It is true that the simple material elements which we have enumerated above may be, and are, curiously combined and arranged, so as to produce the human body. But after this is accomplished, we are left as far as ever from any explanation as to how the mere arrangement and peculiar juxta-position of the material atoms, thus composing such a body, can produce the

prodigious powers of intellect which have been developed in the history of the progress of the human mind.

75. But even admitting a supposition apparently so impossible, the question of personal identity, which we have referred to above, will raise an insuperable objection to it. Physiologists and anatomists have proved that the matter which composes our bodies is subject to continual change. Every part of our organisation, even to the innermost cores of our bones, is subject to this never-ceasing process of mutation. The food which we take into our stomachs contains, combined with some other matters, all the constituents necessary to compose our bodies. In the process of digestion, those parts which are unsuited to our bodies are rejected, and the several suitable parts passing into the blood, are carried by it through the circulating apparatus to all parts of the system; to the bones, as well as to the flesh and softer parts; the peculiar constituents necessary for the maintenance of each part respectively being deposited there in the proper proportion, and the waste carried away. This process of constant renovation and removal of used-up matter—of offal, as it were—goes on equally throughout the bones as throughout the softer parts. Now, it will be evident that, in such an unceasing process of rejection and renovation, the entire mass of matter composing the body must in a certain period, longer or shorter, undergo a complete change, so that, corporeally speaking, an individual, at any given period of his life, has not in his entire composition a single material atom which he had at a certain previous period. It was the opinion of former anatomists and physiologists, that the body undergoes this complete change of the matter composing it every seven years; but more recent and exact observations and calculations, founded upon rigorous analysis of the phenomena of digestion, circulation, respiration, and other less important functions, have proved this estimate to err by excess.

The 116 lbs. weight of water which forms three-fourths of the matter composing our bodies, is rejected with great rapidity in respiration, transpiration, and natural discharge. The carbon is expired with each action of the lungs in large quantities, combined with oxygen, another constituent of our bodies, in the form of carbonic acid. The lime escaping in other ways is rejected from our bones, and replaced by a fresh supply. There is not a movement of the body, whether voluntary or involuntary; not an action of a member, a muscle, or a nerve; not a pulsation of the heart or of an artery; not a peristaltic motion of the intestines, which is not the proximate cause of the rejection of used-up matter and the demand for a fresh supply from the digestive apparatus, just as in a machine the

wear and tear of the parts is proportional to the force and continuance of their motions.

76. Although the rapidity with which the materials of the body are thus changed varies in comparing one individual with another, according to their varying habitudes and occupations, it appears that a total change of the material constituents of the body takes place within an interval much shorter than was supposed by the early physiologists. According to some authorities, the average length of this interval does not exceed thirty days. It is, however, generally agreed that it is a very brief period.*

77. This then being the case, let us again ask what is it that was identical in the Duke of Wellington dying at Walmer in Sept. 1852, with the Duke of Wellington commanding at Waterloo in June, 1815? Assuredly it was not possible that there should have been a single particle of matter common to his body on the two occasions. The interval consisting of thirty-seven years and two months, the entire mass of matter composing his body must have undergone a complete change several hundred times—yet no one doubts that there was *something* there which *did not* undergo a change except in its relation to the mutable body, and which possessed the same thought, memory, and consciousness, and constituted the personal identity of the individual; and since it is as demonstrable as any proposition in geometry that *that something* which thus abode in the body, retaining the consciousness of the past, could not have been an atom, or any number of atoms, of matter, it must necessarily have been something *not matter*, that is to say, something *spiritual*.

Habituated for so long a period to the rigorous logic of physics and mathematics, I confess I can see nothing in its results more conclusive than this proof of the existence of a spiritual essence connected with the human organisation. At this point, however, the support which the physical inquirer can offer to the theologian terminates. If there is nothing in the disorganisation of the human body and the phenomena of death to demonstrate the simultaneous destruction of the spiritual principle, the existence of which is thus established, there is, on the other hand, nothing to prove its continued existence, and for that we are thrown upon the resources of revelation, and this might indeed have been foreseen; for if the continued existence of the spirit, or, in other words, a future state, were capable of demonstration by the

* We are not aware of any dissentient from the complete periodical change of matter composing the body, except Professor Milne Edwards, who, without absolutely denying the principle, thinks that it has not been satisfactorily demonstrated.

ordinary faculties of the mind, it would have been incompatible with the divine economy to have rendered it the subject of revelation. God does not suspend the laws of nature to reveal by miraculous means those truths which are discoverable by the exercise of our natural faculties.

78. As the motions and changes produced upon inert matter are physical and mechanical, so human actions are moral and intellectual phenomena. By duly comparing together the former, we are enabled to arrive at generalisations which are the expression of laws, the knowledge of which enables us to foresee, with certainty and precision, how any proposed bodies will comport themselves at any future time, and in any given place, under given conditions. It might, therefore, be naturally expected that the moral and intellectual phenomena of human actions, coming as truly within the range of natural facts as mere physical phenomena, could be equally classified and generalised, and that, consequently, natural laws might be equally established, by the knowledge of which this latter class of phenomena could, under given conditions, be predicted as clearly and certainly as the former.

79. An essential difference, however, between the two classes of phenomena renders a corresponding distinction in the expression of the general laws to which they are subject, necessary. Bodies consisting of mere inert masses of matter are susceptible of no motion save what they derive from the operation of external forces; and when such forces are given, their effects can be calculated and predicted. But the moral and intellectual phenomena here referred to, proceed from an internal and spontaneous act of the will of the individual, which cannot be known antecedently by the individual himself, and still less by others. The will also being absolutely free, the individual may, under given conditions, act in any conceivable manner; and consequently, as regards such an individual, the actions cannot be reduced like physical facts to a general law. Men being thus free agents, and their actions being subject to impulses arising from characters, temperaments, passions, surrounding excitements and personal circumstances infinitely various, it might naturally be expected that the record of the actions of any large society of individuals, such as the population of a city, province, or country, would present a confused and heterogeneous mass of facts altogether unsusceptible of rule, law, or generalisation; and that, consequently, such record preserved of the past would throw no light whatever upon the probable future of the conduct of such a multitude of free agents.

80. Careful and accurate analyses of the acts of men, so far as

they have been registered in public records entitled to confidence, prove, however, that such is not the case; and that although they individually act with perfect freedom of will, yet their acts collectively conform to laws scarcely less rigorous than that of gravitation, and that, consequently, although the freedom of individual will renders it impossible that the individual acts can be predicted, the same impossibility is not at all applicable to collective acts. On the contrary, statistical records prove incontestably that acts which, taken individually, cannot for a moment be doubted to proceed from the impulses of a free and independent will, taken collectively, recur with as much regularity and precision as the fall of a heavy body by gravitation. It is true that such acts, when classified and generalised, give average results from which the individual cases depart more or less on the one side than on the other; but this is no more than takes place with the physical phenomena of inert matter, all of which oscillate round a mean state, the departures from which have received the name of *perturbations*. In moral and intellectual, as well as in physical and mechanical phenomena, there are also perturbations, but, like the latter, these are also confined within narrow limits. The sole difference in the two classes of natural effects being, that in the one case the condition of bodies may be predicted individually, while in the other it can only be predicted collectively.

81. Those who have prosecuted their researches most extensively in the modern science of Statistics, have proved that the effects of the free will of individuals composing large societies completely neutralise each other, and that such communities taken collectively act as if the whole body had by common consent agreed to follow a certain prescribed course of conduct, not only in matters which might be imagined to be more or less of common interest, but even in those in which no feeling could be imagined to be engaged, save the will, taste, personal inclination, or even caprice, of the individual.

82. There is, perhaps, no act of our lives which so exclusively concerns and interests us personally as that of marriage. Although parents and friends must be admitted to exercise more or less influence, yet, in the main, individuals of the different sexes are united together by their personal choice and inclination. This being the case, it might be imagined that the frequency of marriages, and the relative ages of the parties contracting them, would be as various as the tastes, feelings, inclinations, and personal characters of the individuals composing the community. Yet we find that such is not the case; but that, on the contrary, not only the frequency of marriages, but the relative ages of the parties contracting them, are subject to laws quite as rigorous as

those which govern the motions of the solar system. Thus we find, that in the same country, in a series of successive years, the same average number of marriages are contracted, the departures from the average being, like the planetary inequalities, small and self-compensatory. If there is a small excess in one year above the average, there is sure to be a corresponding deficiency in another.

Thus, for example, in England and Wales during the five years from 1845 to 1849 inclusive, the average number of marriages was 142800, and the actual number in each year varied from this average by not more than a few hundreds. In 1851 and 1852, with an increased population, the average number was increased to 156000, from which the variations were equally inconsiderable. In countries, however, where statistical registers are kept with more circumstantial precision than in England, results affording more striking illustrations of these principles may be obtained. In Belgium, for example, to the statistics of which the labours and talents of M. Quetelet have been directed, some very remarkable circumstances bearing on this question have been developed. Thus, it appears that, for a series of years before and after 1840, the average number of marriages contracted in that country was 29130. How completely obedient the population was in the fulfilment of this statistical law, may be seen by the following exact number of marriages contracted in the five years succeeding 1840:—

YEARS.	MARRIAGES.
1841	29876
1842	29023
1843	28220
1844	29326
1845	29210

Thus it appears that in 1841, 1844, and 1845, the number of marriages exceeded, while in 1842 and 1843 they fell just as far short of the average; just as the velocity of a planet near its perihelion exceeds, and near its aphelion falls short, of its mean motion.

83. But this is neither the only, nor by any means the most remarkable, example of the play of general laws in human actions, which, of all others, must be admitted to be the most completely voluntary. Thus, for example, when a man of 30 chooses a wife above 60, he can scarcely be imagined to be controlled by the influence of parents. Yet it appears that the frequency of such marriages is as regular as the annual motion of the sun. Take the following examples. In Belgium, the average number of men not above 30 marrying women above 60 annually is 6, and the

departures from this either way is usually limited to 5 or 7. If in one year there are 7 such marriages, it is sure to be preceded or followed immediately or mediately by another year in which the number is only 5. Again, the number of men between 30 and 45 contracting marriage with women above 60 is annually 18, subject to a small occasional variation one way or the other. In the same way, it appears that the number of men from 45 to 60 marrying women above 60 is annually 27.

The same regularity is found to characterise the number of marriages between couples within any other prescribed limits of comparative age.

84. The number of children resulting from each marriage cannot be considered as depending on will. But assuredly the calling into the world of illegitimate children must be admitted to have the character of a voluntary act; yet it is found, that in each country, the annual number of illegitimate children bears a fixed ratio to the number of marriage-born. In France and Belgium this ratio is 1 to 13. In England the proportion is found to be exactly the same. and this appears to occur, from year to year, in both countries with all the regularity of physical law.

85. The statistics of crime being especially susceptible of exact record, have been submitted to the same careful examination by M. Quetelet, from whose researches it appears, that in the same country the same number of crimes of the same description are committed annually; and this curious result is found equally to attend those classes of crimes which it would seem most impossible to foresee. But, connected with these criminal statistics, there is a circumstance still more curious and remarkable. It necessarily happens, in the administration of criminal justice, that, through the want of sagacity in the examining magistrates, and a multitude of fortuitous circumstances surrounding the accused, a considerable number of guiltless persons are brought to trial. Now, will it be believed, that such is the prevalence of general laws, that even in this class of moral phenomena, founded on the results of fallible judgment, a rigorous law prevails, and we find that, in each country, the proportion of persons charged with offences who are acquitted, is from year to year the same? Thus, for instance, in France, 39 in every 100 of those accused are as regularly acquitted as if the decisions of the juries were made by putting 61 black balls and 39 white ones into a box, and deciding the fate of the criminals by ballot.

86. It is not only, however, voluntary acts which are subject to this numerical regularity. Collectively speaking, persons remember and forget certain things with as much regularity as if memory and attention were the result of wheel-work. A very

common instance of forgetfulness is presented by persons posting letters without any address written upon them. The number of times this act of obliviousness annually happens is known with the greatest precision, inasmuch as such letters are transferred to and recorded in a bureau specially devoted to the purpose in each post-office. Now, it is found by the Post-Office returns in England and France, that the number of these unaddressed letters in each country is almost exactly the same from year to year. In London the number of such letters is about 2000, being at the rate of above 6 per day.

But connected with this is another circumstance equally remarkable. A certain proportion of these letters is found to contain money and other valuable enclosures; and, like the whole number, this proportion is also invariable.

87. The conclusion at which we arrive then is, that the great principle in virtue of which the Author of nature carries out His purposes by the operation of general laws is not, as it would first appear, incompatible with the freedom of human agency, and therefore with man's moral responsibility. The same character of generality attaches to the laws which govern the moral and intellectual phenomena of human actions, considered collectively, as those which attach to mere physical phenomena. But these laws not being applicable to human actions, considered individually, leave free will and moral responsibility inviolate.

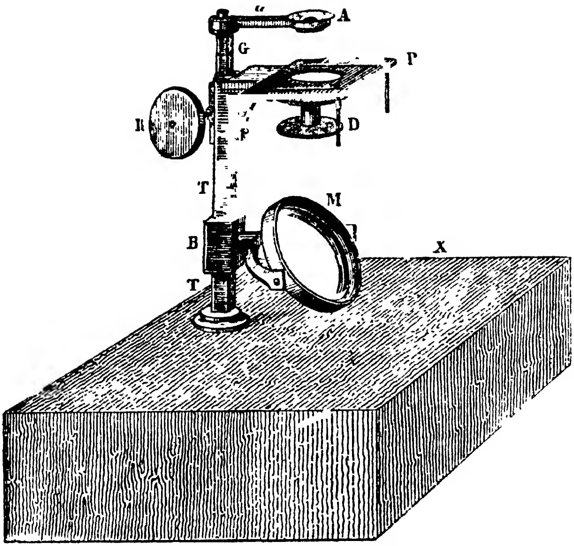


Fig. 15.—Simple Microscope.

MAGNIFYING GLASSES.

1. Magnifiers intermediate between spectacle-glasses and microscopes.—2. Variously mounted.—3. Extensive use in the arts.—4. Their magnifying power explained.—5. Visual magnitude.—6. Standard of visual magnitude.—7. Distance of most distinct vision.—8. Visual magnitude at ten-inch distance.—9. Magnifying power of a convex lens.—10. Effect of the same lens with different eyes.—11. Superficial and cubical magnifying power.—12. The eye to be placed close to the lens.—13. Magnifying power depends on focal length.—14. Focal length depends on convexity and materials of lens.—15. Lenses of different materials.—16. Spherical aberration less with a greater refracting material.—17. Diamond lens.—18. Magnitude of lens greater with more refracting material.—19. Advantages of gem lenses.—20. Superseded nevertheless by the improvement of compound microscopes.—21. Magnifiers for reading.—22. For miniature-painters and engravers.—23. For watch-makers, jewellers, &c.—24. Supports for these.—25. Pocket magnifiers.—26. Coddington lens.—27. Doublets.—28. Their optical effects.—29. Their advantages over single lenses.—30. Method of mounting them; triplets.—31. Mounting of hand-doublets.—32. Method of mounting doublets of high power for dissection and similar purposes.

1. Magnifying glasses hold an intermediate place between the spectacle glasses, used by weak-sighted persons, and the microscope; and when they possess considerable magnifying power, they

are sometimes called simple microscopes; but the term microscope is more generally applied to that class of optical instruments which consists of a combination of lenses, which are applicable to the examination of the most minute objects, and with amplifying powers much more extensive.

2. Magnifiers are very variously mounted according to the uses to which they are applied. The more simple forms, and those which have the least amplifying power, consist of a single lens, which is either convex on both sides, or plano-convex, or which may be concave on one side and convex on the other, provided the convexity be greater than the concavity. In fine, whatever be its form, it is essential that convexity shall prevail.

3. These glasses are of very extensive use in the arts. In all cases in which the objects operated upon are minute, the interposition of a magnifier is found advantageous, and often indispensable; thus, they are invariably used in different mountings by watch-makers, jewellers, miniature-painters, engravers, and others.

4. To render our explanation of these very convenient instruments intelligible, it will be necessary that the reader should be previously more or less familiar with what has been already explained in our Tracts on the Eye, on Optical Images, and on Spectacles; we shall, therefore, take for granted, that the contents of these Tracts are known to the reader.

We know no subject respecting which more inexact and erroneous notions prevail, than the amplification or magnifying effect produced by all optical combinations, from the simple convex lens to the most powerful microscope. The chief cause of all this confusion and obscurity may be traced to a neglect of the proper distinction between visual and real magnitude. The eye, as has been already explained, takes no direct cognizance of real magnitude, which it can only estimate by inference and comparison with the impressions of the sense of touch; these inferences and comparisons being often attended with complicated calculations and reasoning. If a proof of this be required, it may be found in the universally observable fact that objects which have the same visual magnitude often have real magnitudes enormously different; thus, for example, the apparent or visual magnitudes of the sun and moon are, as every one knows, equal; yet the real diameter of the sun is more than 400 times that of the moon.

5. It must be remembered that visual magnitude is determined by the divergence of lines drawn from the eye to the extreme limits of the object; it is measured, therefore, not like real magnitude by miles, feet, and inches, but by degrees, minutes, and seconds; thus, while the real diameter of the moon measures

about 2000, and that of the sun about 887000 miles, the visual diameter of the one and the other measures about half a degree.

The magnitudes of objects, as they appear with magnifying glasses, are all visual and not real. When an object seen by the interposition of such an instrument is said to be magnified so many times, it is therefore meant that it is so many times greater than it would be if the same object were seen with the naked eye; but since it has been shown in our Tract on the eye, that the visual magnitude of the same object seen with the naked eye varies, being greater as its distance from the eye is less, it follows, that the visual magnitude seen with the naked eye is an indefinite and variable standard, and in order that the visual magnitude of an object taken as the standard of magnifying power should be definite, it is necessary that the distance at which the object is supposed to be viewed by the naked eye should be stated. When, however, a person without any previous scientific instruction views an object with a magnifier, he becomes instantly conscious of its amplification; that is, that it appears larger than it would appear if he had viewed it without the interposition of the magnifier. The question is then, at what distance from his eye such a person would suppose the object to be looked at without the magnifier; and the reply which has been generally given to this question is, that he would suppose it to be viewed at that distance at which he would see it most distinctly.

6. This being admitted then, microscopists have generally agreed that the visual magnitude viewed with the naked eye, which should be taken as the standard of comparison in expressing the effect of magnifiers, is that which the object would have when viewed at the distance at which objects are most distinctly seen.

7. But here another difficulty arises. In the first place, the distance at which one individual can see an object most distinctly is not the same as that at which another will see it most distinctly; thus, while a far-sighted person will see most distinctly at the distance of 15 or 16 inches, and cannot see at all at the distance of 5 or 6 inches, a near-sighted person will see most distinctly at the latter distance, and only confusedly and indistinctly at the former. But even the same individual will see the same object most distinctly at one distance when it is strongly illuminated, and at a much less distance when it is feebly illuminated.

The distance of most distinct vision is therefore a variable and uncertain standard of comparison.

8. But there is one thing which is perfectly definite and certain. The visual magnitude of an object, at a given distance, is always the same, and quite independent of the powers and qualities of the eye which views it; it may, or may not, be distinctly

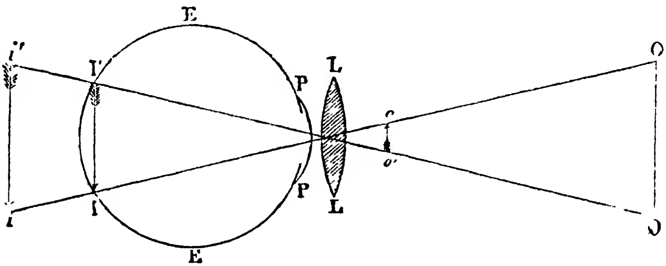
seen, or seen at all; but if seen, it can have but one visual magnitude. Thus an object, such as a coin, placed with its surface at right angles to the line of sight, at a distance from the eye equal to 10 times its own diameter, will have a visual diameter of $5\frac{3}{4}°$, and neither more nor less, no matter by what eye it is viewed. Seeing, then, that the distance of most distinct vision varies with different observers, and even with the same observer under different circumstances, and cannot therefore be taken as a standard of reference for visual magnitude, it has been generally agreed that magnifying powers shall be arithmetically expressed, by reference to visual magnitudes seen at 10 inches distance. Thus, if we say that such or such a magnifier magnifies an object three or four times, it is meant that it exhibits that object with a visual magnitude three or four times as great as that which the same object would have if viewed with the naked eye at 10 inches distance.

This distance of 10 inches has not been selected arbitrarily. It is considered to be about the distance at which average eyes would see an object most distinctly. It has the further convenience of lending itself with facility to calculation by reason of its decimal form. In other countries, the same distance very nearly has been adopted as a standard. Thus, French microscopists take 25 centimetres, which is a very small fraction less than 10 inches, as their standard.

9. This conventional standard being accepted, let us see in what manner an object is made to appear magnified by the interposition of a single convex lens.

Let E E fig. 1, represent a section of the eye, and *o o′* a small object placed at a much less distance from the eye than is com-

Fig. 1.



patible with distinct vision. According to what has been explained in former tracts, it will appear that the cause of indistinct vision is, in this case, that the image of *o o′*, produced by the humours of the eye, is formed not as it ought to be on the

retina at I I′, but behind it at *i i′*. According to what has been explained of optical images, the interposition of a lens, L L, of suitable convexity, will bring forward the image from *i i′* to I I′, and will therefore render the perception of the object distinct.

Now, it is most important to observe in this case, that the visual magnitude of the object, measured by the angle formed by the lines *o* I and *o′* I′, will be exactly the same as it would be if the eye could have seen the object *o o′* without the interposition of the lens: from which it appears that the lens does not, as is commonly supposed, directly augment the visual magnitude of the object, but only enables the eye to see the object with distinctness at a less distance than it could so see it without the interposition of the lens. We say *directly*, because, although the lens does not augment the visual angle of the object in the position in which it is actually viewed, yet, by enabling the eye to see it distinctly at a diminished distance, the visual angle of distinct vision, and therefore the apparent magnitude of the object, is increased in exactly the same proportion as the distance at which it is viewed is diminished.

To understand the magnifying effect of the lens, we must consider that the observer, seeing the object *o o′* with perfect distinctness, obtains exactly the same visual perception of it as if the object having the same visual magnitude were placed at that distance from the eye at which his vision would be most distinct. Let the lines passing through the extremities of the object therefore be prolonged to this distance of most distinct vision, and let an object, O O′, be supposed to be placed there, similar in all respects to the object *o o′*, and having the same visual magnitude. It will be evident, from what has been stated, that *o o′*, as seen with the lens, will have precisely the same appearance as the object O O′ would have if seen with the naked eye. The observer, therefore, considers, and rightly considers, that the magnifying power of the lens is expressed by the number of times that O O′ is greater than *o o′*; or, what is the same, by the number of times that the distance of O O′ from the lens, that is the distance of most distinct vision, is greater than the distance of the object from the lens.

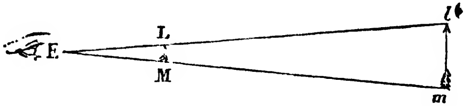
It follows, therefore, generally, that the magnifying power of the lens will be found by dividing the distance of most distinct vision by the distance of the object from the lens.

10. Adopting this method of estimating the magnifying power, it would follow that the same lens would have different magnifying powers for different eyes, inasmuch as the distance of most distinct vision for short sight is less than that for average sight, and less for average sight than for far sight.

To make this more clear, let E, fig. 2, represent an average

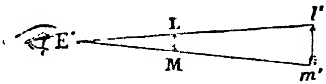
sighted eye; E′ (fig. 3) a short-sighted eye, and E″, (fig. 4, a far-sighted eye. Let the same small object, L M, be placed at the same

Fig. 2.



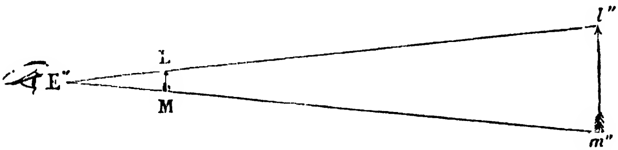
distance from each of them, and let the distance of most distinct vision for the first be E *l*; for the second E′ *l*′, and for the third

Fig. 3.



E″ *l*″. If, by the interposition of a lens, the object L M be rendered distinctly visible to each of these three eyes, it will appear at *l m*

Fig. 4.



to E, at *l*′ *m*′ to E′, and at *l*″ *m*″ to E″; its apparent magnitude, therefore, to the three eyes will be in the exact ratio of their respective distances of most distinct vision, and consequently the magnifying power to E′ will be less, and to E″ greater than to E.

It must, however, be observed, that in this, which is the commonly received explanation, a circumstance of some importance is omitted, which will modify the conclusion deduced from it. To produce distinct vision with a given lens, L L, the distance of the object from the lens will not be the same for different eyes; for short sight the object must be nearer, and for long sight more distant than for average sight.

Now, if this variation of the distance from the lens, or of the focus, as it is called, for different eyes vary in the same proportion as the distance of most distinct vision (and it certainly does not differ much from that proportion), it will follow, contrary to the received doctrine, that the magnifying power of the same lens, will be the same for all eyes, whether they have average sight, long sight, or short sight.

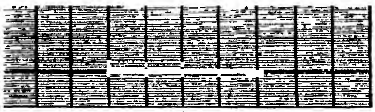
11. It is contended by some that the magnifying power is more properly and adequately expressed by referring it to the superficial than to the linear dimensions of the objects.

To illustrate this, let us suppose the object magnified to be a square such as *a*, fig. 5. Now, if its linear dimensions, that is its sides, be magnified 10 times, the square will be increased to the size represented at A (fig. 6); its height and breadth being each increased 10 times, and its superficial magnitude being consequently increased 100 times, as is apparent by the diagram.

Fig 5

a

Fig. 6.



A

Now, it is contended, and not without some reason, that when an object, such as *a*, receives the increase of apparent size, represented at A, it is much more properly said to be magnified 100 than 10 times.

Nevertheless, it is not by the increase of superficial, but of linear dimensions that magnifying powers are usually expressed. No obscurity or confusion can arise from this, so long as it is well understood that the increase of linear, and not that of superficial dimension, is intended. Those who desire to ascertain the superficial amplification, need only take the square of the linear; thus, if the linear be 3, 4, or 5, the superficial will be 9, 16, or 25, and so on.

It might even be maintained, that when an object having length, width, and thickness, a small cube or prism of a crystal for example, is magnified, the amplification being produced equally on all the three dimensions, ought to be expressed by the cube of the linear increase; thus, for example, if the object, being a cube, be magnified 10 times in its linear dimensions, it will acquire 10 times greater length, 10 times greater breadth, and 10 times greater height, and will consequently appear as a cube of 1000 times greater volume.

In this case, however, as in that of the superficial increase, the calculation is easily made by those who desire it, when the linear increase is known.

12. In all cases in which magnifying lenses are used, except where the lens is large, and the magnifying power low, the eye of the observer should be placed as close as possible to the lens, the pupil being as nearly as possible concentric with the lens; for since the pencils of rays, which proceed from the extreme points of the object, intersect at an angle equal to that formed by lines drawn from the extremities of the object to the centre of the lens, they will diverge after passing through the lens, at the same angle; and the farther the eye is removed from the lens, the more rays it will lose, and beyond a certain limit of distance, a part only of the object will be visible.

13. Since eyes of average sight are adapted to the reception of parallel rays, an object seen through a lens by them will be distinctly visible, only on the condition that its distance from the lens shall be equal to the focal length; for, in that case, the rays which diverge from each point of the object, will emerge from the lens parallel, and therefore suitable to the power of the eye.

It is for this reason that the magnifying powers of lenses are estimated, by comparing their focal lengths with the distance of distinct vision. For since the focal length is always the distance of the object from the lens for average eyes, the distance of distinct vision, divided by it, will, according to what has been explained, be the magnifying power of the lens for such eyes.

14. The focal length of a lens will be less in proportion as its refracting power upon the light transmitted through it is greater; but the refracting power of the lens depends partly on its convexity and partly on its material.

With the same material the refracting power will be greater and the focal length less, as the convexity is increased; and, on the other hand, with a given convexity, the refracting power will be greater, and the focal length less, as the refracting power of the material, of which the lens is made, is greater. Thus, for example, if two lenses be composed of the same sort of glass, that which has the greater convexity will have the less focal length; and if, on the other hand, two lenses, one composed of glass and the other of diamond, have equal convexities, the latter will have a less focal length than the former; because diamond has a greater refracting power than glass.

15. It will be evident, from what has been explained, that if two lenses be formed of materials having different refracting powers, such for example as glass and diamond, so as to have equal focal length, that which has greater refracting power will have the less convexity.

If two lenses therefore be formed, having the same magnifying

power, one of glass and the other of diamond, the latter will have less convexity than the former.

From what has been explained on the subject of spherical aberration, in our Tract upon Optical Images, it will be understood, that the more convex a lens is, the less its diameter must be, for if its diameter exceeds a certain limit relatively to its convexity, the spherical aberration will become so great as to render all vision with it confused and indistinct. This is the reason why all lenses of high magnifying power and short focal length are necessarily small.

16. But since the spherical aberration depends on, and increases with the convexity of the lens, other things being the same, it follows that if two lenses, composed of different materials, have equal focal lengths, that which has the less convexity will also have less spherical aberration.

17. Now, as according to what has been explained above, a diamond lens has less convexity than a glass lens of the same focal length, it will, if it had the same diameter, have less spherical aberration, or, what is the same, it will admit of being formed with a greater diameter, subject to the same aberration.

18. In lenses of high magnifying powers, and which are consequently of small dimensions, any increase of the diameter which can be made without being accompanied with an injurious increase of aberration, is attended with the advantage of transmitting more light from each point of the object to the eye, and therefore of rendering the object more distinctly visible. It was on this account that, when single lenses of high magnifying power were thought desirable, great efforts were made to form them of diamond, and other transparent gems having a refracting power greater than that of glass.

19. Sir David Brewster, who first suggested the advantage of this, succeeded in getting lenses of great magnifying power, made of ruby and garnet; he considered those made from the latter stone to surpass every other solid lens: the focal length of some of those made for him was less than the 1-30th of an inch, the magnifying power being more than 300.

20. All these and similar efforts made by Messrs. Pritchard and Varley, aided by the genius and science of the late Dr. Goring, have, however, happily for the progress of science, been subsequently rendered unnecessary by the invention of methods of producing good achromatic object-glasses of high power for compound microscopes, so that the range of usefulness of simple microscopes, or magnifying glasses, is now limited to uses and researches in which comparatively low magnifying powers are sufficient.

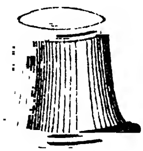
21. The most feeble class of magnifying glasses are those occa-

sionally used for reading small type, by persons of very weak sight; they consist of double convex lenses of 5 or 6 inches focal length, and having consequently a magnifying power no greater than two; they are usually double convex lenses, from 2 to 3 inches in diameter, mounted in tortoise-shell or horn, with convenient handles.

22. Magnifiers of somewhat shorter focal length and less diameter, similarly mounted, are used by miniature-painters and engravers.

23. Lenses having a focal length of about one inch, set in a horn cell, enlarged at one end like the wide end of a trumpet, the magnitude being made to correspond with the socket of the eye, as represented in fig. 7, are used by watch-makers. The wide end being inserted under the eyebrow, is held in its position by the contraction of the muscles surrounding the eye-ball, and the minute work to be examined, is held within an inch of the lens set in the smaller end of the horn case; if the focal length be an inch, the magnifying power of such a glass, for average eyes, will be ten.

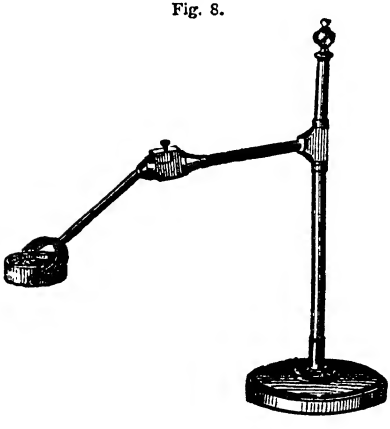
Fig. 7.



Glasses somewhat similarly mounted are used by jewellers, gem-sculptors, and other artists.

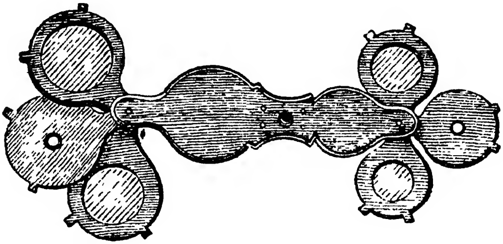
24. To relieve the artisan from the fatigue of holding the magnifier in the eye-socket or in the hand, a stand with a moveable socket is sometimes resorted to, such as that represented in fig. 8. A horizontal arm slides upon a vertical rod, upon which it can be fixed at any desired height by a tightening screw. This arm consists of two joints, connected together by a ball and socket, by which they can be placed at any desired inclination; at the extremity of the lower arm a fork supports a ring-shaped socket, made to receive the magnifier.

Fig. 8.



25. Very convenient pocket magnifiers are mounted in tortoise-shell or horn cases, in the form shown in fig. 9. Lenses of

Fig. 9.

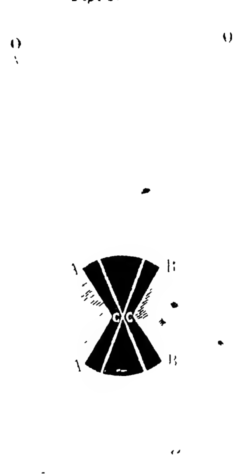


different powers are provided which may be used separately or together; when they are used together, however, the interposition of a diaphragm is necessary to diminish the effects of spherical aberration by cutting off the lateral rays.

Lenses thus mounted are well fitted for medical use, and for certain researches in natural history.

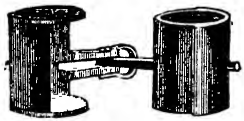
26. When a higher power is required than that which these common magnifiers afford, a magnifying glass, called from its inventor a Coddington lens, is used with much advantage. To produce such a lens, a solid ball or sphere of glass, about $\frac{1}{2}$ an inch in diameter, is cut round its equator, so as to form round it an angular groove, leaving two spherical surfaces on opposite sides uncut. The angular groove is then filled up with opaque matter, the circular edge of the groove serving as a diaphragm between the two spherical surfaces. A section of such a lens is shown in fig. 10, where A B and A′ B′ are the two spherical surfaces left uncut, and A C A′ and B C B′ the section of the angular groove filled with opaque matter. The course of the rays passing through it from any point such as O, is shown by the lines O *o*, and it will be evident from the

Fig. 10



mere inspection of the figure, that the effect of the lens upon the rays will be precisely the same, wherever the point O may be placed; this lens, therefore, gives a large field equally well defined in all directions, and since it is no matter in what position it is held, it is very convenient as a hand and pocket glass; it is usually mounted in a small case, such as is shown in fig. 11, which can be carried in the waistcoat pocket.

Fig. 11.



27. Magnifying glasses of low powers, such, for example, as those which range from 5 to 40, may be constructed with much advantage in one or the other of the above forms. When, however, higher powers are necessary, the use of such lenses, with very short focal length, is attended with much practical inconvenience, which has been removed by the use of magnifiers, consisting of two or more lenses combined. The combinations of this kind which are found most efficient, consist of two or three plano-convex lenses, with their convex side towards the eye; these are called doublets and triplets.

28. After what has been explained in our Tract upon Optical Images, the principle upon which these magnifiers depend will be easily understood.

Let E E and D D, fig. 12, represent the two lenses of a doublet, and let *o o* be a small object placed before D D, at a distance from it less than its focal length. According to what has been explained, D D will produce an imaginary image of *o o* at *i i*, more distant from D D than *o o*, so that an eye placed behind D D would receive the rays from *o o*, as if they had diverged from the corresponding points of *i i*.

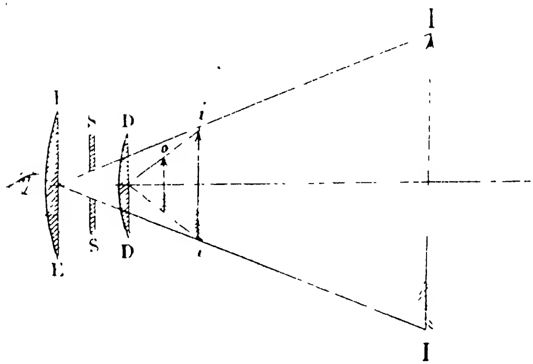
But instead of being received by an eye placed behind D D, these rays are received by the other lens E E; the image *i i* therefore plays the part of an object before the lens E E, and being at a distance from E E less than the focal length of the latter, an imaginary image of *i i* will be produced at I I; the rays, after passing through E E, entering the eye as if they had come from the corresponding points of I I.

To cut off all scattered rays not necessary for the formation of the image, a stop or diaphragm, S S, consisting of a circular disc of metal, with a hole in its centre, is interposed between the two lenses.

29. Such a combination, when high powers are necessary, has several advantages over an equivalent single lens. In the first place, the effect of spherical aberration is much less, and secondly,

the object can be placed at a much greater distance from the anterior lens D D, and can consequently be more conveniently

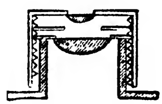
Fig. 12.



manipulated, if it be desired to dissect it, or to submit it to any other process; it can also be illuminated by a light thrown upon that side of it which is presented to the glass; this could not be done if it were nearly in contact with the glass, which must necessarily be the case by reason of its very short focal length, if a single lens were used.

30. It was recommended by Dr. Wollaston, the inventor of these doublets, to give the two lenses composing them unequal focal lengths, that of E E being three times that of D D.

Fig. 13.



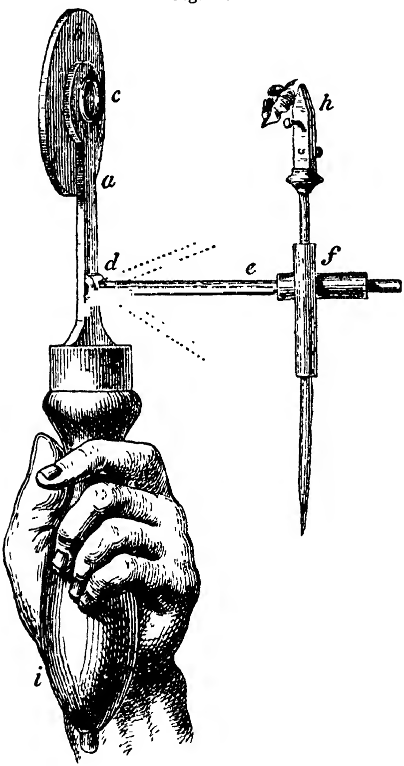
The lenses are usually set in two thimbles, one of which screws into the other, as shown in fig. 13, so that they can be adjusted as to their mutual distance, so as to produce the best effect. When still higher powers are sought, the lens D D is replaced by two plano-convex lenses, in contact, which taken together play the part of the single lens D D in the doublet; this combination is called the triplet.

When a very low magnifying power is required, the lenses E E and D D may be separated, by unscrewing.

31. The lenses, whether of a doublet or a triplet, being thus properly mounted, expedients must be adopted to enable the observer to apply them conveniently to the object under examina-

tion. The most simple method of effecting this would be to hold the lens to the eye with one hand, and to present the object before it at the proper distance with the other. But even in this case it would be necessary that the lens should be attached to a convenient handle, and unless the magnifying power were very low, the steadiness necessary to retain the object in the focus could not be imparted to it, and while the observation would be unsatisfactory the fatigue of the observer would be considerable.

Fig. 14.



When high powers are used, every motion of the object is as much magnified as the object itself, and consequently in such cases the most extreme steadiness is indispensable.

Whatever be the form of the mounting, therefore, it is necessary that the object should be supported by some piece attached to that by which the doublet itself is supported, so that it may be steadily held in the axis of the lenses, and that its distance from them may be varied at pleasure, by some smooth and easy motion, by which the observer can bring the object to the proper focus.

The means by which these ends have been attained vary according to the use to which the microscope is to be applied, to its cost, the taste and fancy of the observer, and the skill and address of the maker.

One of the most convenient forms of mounting, for a common hand microscope is shown in fig. 14.

The doublet is inserted in a socket *c* made to fit it; the screen

b protects the eye from the light by which the object is illuminated, an arm *e* is jointed at *d*, so that it can be turned flat against *a*, when the instrument is not in use, and can be inclined to *a*, at any desired angle. This arm being round, a sliding tube *f* is placed upon it, fixed to another tube at right angles to it, in which a vertical rod slides, to the upper end of which is attached a forceps or any other convenient support of the object under examination.

Several doublets or triplets of various powers may be provided, any of which may be inserted at pleasure in the socket *c*.

32. When still greater steadiness is required, and greater bulk and higher price do not form an objection, the arm and socket bearing the doublet are fixed upon a vertical pillar, screwed to a table with proper accessories for adjusting the focus and illuminating the object.

The arrangement adopted in the simple microscopes of Charles Chevalier, shown in fig. 15, p. 97, may be taken as a general example of this class of mounting.

The case in which the instrument is packed serves for its support when in use. A square brass pillar T T, screwed into the top of this case X, has a square groove cut along one of its sides, in which the square rod G is moved upwards and downwards by a rack and pinion R; at the top of this rod, a horizontal arm *a* is attached, at the end of which a socket is provided to receive the doublets; several of which having different powers are supplied with the instrument.

The object under observation is supported on the stage P, firmly attached to the upper end of the square pillar T T; in this stage is a central hole, through which light is projected on its lower surface when the object is transparent, and the quantity of this light is modified by means of an opaque disc D, pierced with holes of different magnitudes.

By turning this disc on its centre, any one of these holes may be brought under the object; when the object is not transparent, the opening in the stage is stopped, and it is viewed by light thrown upon its upper surface.

A square box B, sliding upon the pillar T T, with sufficient friction to maintain it at any height at which it is placed, carries a reflector M, by which light is projected upwards to the opening of the stage P, this light being more or less limited in quantity by the orifice of the diaphragm D, which is presented in its path.

In this instrument the object is brought into focus by moving the arm which carries the doublet up and down, by means of the rack and pinion R, the stage supporting the object being fixed. The same effect might be, and is in some microscopes, produced

by moving the stage supporting the object to and from the lens: but when the instrument is applied to dissection, it is necessary to keep the subject dissected immoveable, and, therefore, not only to maintain the stage stationary, but to render it so solid and stable that it will bear the pressure of both the hands of the operator while he manipulates the dissecting instruments; on this account the stage is often made larger than is represented in the figure, and supported by a separate pillar.

The arm *a* carrying the doublet is also sometimes fixed in a square socket on the top of the rod G, so that it can be moved to and fro in the socket, while the socket itself can be turned upon the rod G; by this combination of motions, the observer can with great convenience move the lens over every part of the object under examination.

Simple magnifiers, with provisions similar to these, are made by the principal opticians, Messrs. Ross, Leland and Powell, Smith and Beck, Pritchard, Varley, and others.

When the object has not sufficient transparency to be seen by light transmitted through it from below, it may be illuminated by a light thrown upon it from above by a lamp or candle, and condensed, if necessary to obtain greater intensity, by means of a concave reflector or convex lens.

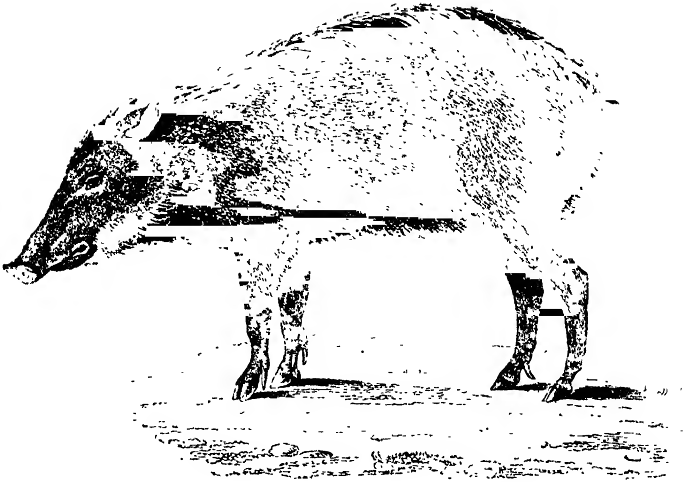


FIG. 26.—THE PECARI, OR SOUTH AMERICAN HOG.

INSTINCT AND INTELLIGENCE.

CHAPTER I.

1. Instinct defined. — 2. Independent of experience or practice. — 3. Sometimes directed by appetite. — 4. A simple faculty independent of memory. — 5. Instinctive distinguished from intelligent acts. — 6. Instinct and intelligence always co-exist. — 7. The proportion of instinct to intelligence increases as we descend in the organic chain. — 8. Opinions of Descartes and Buffon — Character of the dog. — 9. Researches and observations of Frederic Cuvier. — 10. Causes of the errors of Descartes, Buffon, Leroy, and Condillac. — 11. Degrees of intelligence observed in different orders of animals. — 12. Accordance of this with their cerebral development. — 13. Opposition between intelligence and instinct. — 14. Consequences of defining their limits. — 15. Example of instinct in ducklings. — 16. In the construction of honeycomb. — 17. The snares of the ant-lion. — 18. Their mode of construction and use. — 19. Spiders' nets. — 20. Fishes catching insects. — 21. Provident economy of the squirrel. — 22. Haymaking by the Siberian lagomys. — 23. Habitations constructed by animals. — 24. The house of the hamster. — 25. The habitation of the mygale, with its door. — 26. Habitations of caterpillars. — 27. Clothing of the larva of the moth. — 28. Dwellings of animals which are torpid at certain seasons. — 29. The Alpine marmot — Curious structure of their habitations. — 30. Method of constructing them. — 31. Singular habits of these animals. — 32. Instincts of migration. — 33. Irregular and occasional migration. — 34. General assembly preparatory to migration. — 35. Occasional migration of monkeys.

1. In contemplating the habits and manners of animals, numerous acts are observed bearing marks of more intelligence and foresight than it is possible to suppose such agents to exercise. Since intelligence, therefore, cannot be admitted as the exciting cause for such actions, they have been ascribed to another power, called INSTINCT, which is defined to be one by which, independent of all instruction or experience, animals are unerringly directed to do spontaneously whatever is necessary for their preservation and the continuance of their species.

2. Instinct, therefore, must be regarded as a simple power or disposition emanating directly from the Creator, and producing its effects, without the intervention of any mental process. These effects, moreover, are susceptible of no modification by experience or repetition. A purely instinctive act is performed with as much facility and perfection at the first attempt as after repetition, no matter how long continued. The new-born infant seizes the mother's breast with its lips, draws the milk from it, and swallows that nourishing fluid—a very complicated physical process—as readily and as perfectly as it does after the daily experience and practice of ten or twelve months. The young bee just emerged from the cell, sets about the highly geometrical process of constructing its complicated hexagonal comb, and accomplishes its work with as much facility and perfection as the oldest inhabitant of the hive.

3. Instinct operates sometimes, but not invariably, by the intervention of physical appetite. Thus animals seek food, and the union of the sexes, not with the purposes which Nature designs to attain by these acts, but for the mere pleasure attending the gratification of appetite and passion. This pleasure is the bait which the Creator throws out to allure them to do what is indispensable for the preservation of the individual and the continuance of the species.

Thus, although animals seek food to satisfy hunger, the act is still instinctive. In the choice of food, that which is hurtful or poisonous is avoided, and that which is nutritious selected. The food which is suitable to the organs of digestion is always that to which the animal directs itself. These organs in some are adapted to vegetable, in others to animal food, and each species accordingly seeks the one or the other. Since it cannot be imagined that these animals are endowed with intelligence by which they are enabled to judge of the qualities of this or that species of aliment, it is clearly necessary to ascribe their acts in choosing always those which are suitable to them, to a power different from and independent of intelligence.

4. While instinct is a simple power, prompting acts apparently

the most complicated, and producing its effects at once in the most perfect manner and without any internal effort on the part of the agent, intelligence, on the contrary, is a faculty consisting of various distinct operations depending on experience and susceptible of indefinite improvement by exercise. The perceptions received from external objects are the data upon which it is exercised. These perceptions are capable of being revived and identified by the faculty called memory. Thus, having once perceived any given object, it is identified upon its recurrence by the consciousness that the perception it produces is the same as that which was formerly produced by it. Thus, objects once seen are known when seen again.

Memory is essential to almost all other acts of intelligence, the most simple of which is that by which the mind infers that any effect which has been once produced will be again reproduced by the same agent under like circumstances: and the oftener such effects are observed to be reproduced, the more strong is the conviction that they will reappear.

5. Instinctive acts are done without any perception or consciousness of their consequences on the part of the agent. Intelligent acts, on the contrary, are performed not only with a consciousness of their consequences, but *because* of that consciousness. They are performed precisely with a view to produce the effects which are known by previous experience to have resulted from them.

6. It must not be supposed that instinct and intelligence cannot coexist, or that the animal endowed with either is necessarily deprived of the other. It is certain, on the contrary, that most animals are more or less gifted with both. In man, constituting the highest link in the chain of animal organisation, the faculty of intelligence predominates in an immense proportion over that of instinct. In passing to the next link, the relation between these faculties undergoes a change so enormous, that naturalists have regarded man not merely as a species of animal, but as an order of organised beings apart, being the sole genus of his order and the sole species of his genus.

7. In descending from link to link downwards along the chain of animal organisation, the play of intelligence is observed to bear a less and less proportion to that of instinct, until we arrive at the last links, where all trace of intelligence is lost, and animal life becomes a mere system of phenomena produced by instinctive impulses.

8. The question of the relative provinces and play of instinct and intelligence in the animal world, has been agitated among philosophers and naturalists from the earliest epochs down to our

own times. Descartes maintained that the inferior animals were mere automata, but that being constructed by Nature, they are incomparably more perfect than any which could be constructed by man. Buffon allowed them sensations, and a consciousness of present existence, but denied them all exercise of thought, reflection, the consciousness of past existence or memory, and the power of comparing their sensations or having ideas. Yet notwithstanding this, in other parts of his works, he admits that a power of memory, active, extensive, and retentive, cannot be denied to certain species. Thus, in his history of the dog, he says that an ardent, choleric, and even ferocious disposition, which renders that animal in the wild state formidable to all around it, gives place in the domestic dog to the most gentle sentiments, the most lively attachments, and the strongest desire to please. The dog, creeping to the feet of its master, places at his disposition its courage, its force, and its talents. It waits his orders merely to execute them; it consults him, interrogates him, supplicates him, understands the slightest signs of his wishes: has all the warmth of sentiment which characterises man, without the light of his reason; has more fidelity, more constancy; no ambition, no selfish interest, no desire of vengeance, no fear save that of its master's displeasure. It is all zeal, all ardour, all obedience. More sensible to the memory of kindness than of injury, it is not disheartened by bad treatment. It submits and forgets, or remembers only the more to attach itself. Far from being irritated by, or flying from him who punishes it, it willingly exposes itself to new trials. It licks the hand which strikes it, offers no remonstrance save the expression of its pain, and disarms the hand which punishes it by patience and submission.*

Thus while Buffon refuses thought to the dog, he admits that he is capable of consulting, interrogating, and supplicating his master, and understanding the signs of his will. But, how, it may be asked, can a dog understand, without understanding? Without the faculty of memory, how can he remember kindness and forget ill-treatment? Buffon, as M. Flourens justly observes, admits as an historian, but he denies as a philosopher, and in spite of his acute understanding, allows his judgment to be influenced by the purpose to which the work on which he is engaged at the moment is directed. As an historian, he has to state facts; and he does so with truth and eloquence. As a philosopher, he has to defend a system; and he closes his eyes on all facts save those which support his hypothesis.

9. During more than a century which elapsed between the

* "Histoire du Chien," vol. 5, p. 186.

epochs of Descartes and Buffon,* the question of the instinct and intelligence of animals was discussed in the spirit of the ancient philosophy on purely metaphysical grounds. It was with Buffon, and soon afterwards with Leroy, that it began to be placed upon the basis of observation and induction; but the first philosopher who reduced it to a definite form and supported his reasoning by observations systematically pursued was Frederick Cuvier. He proposed to determine the limits of the intelligence of different species; those which separate intelligence generally from instinct; and those in fine by which human intelligence is distinguished from that of inferior animals. These three points being once established, the long vexed question of animal intelligence was presented under a new aspect.

10. When Descartes and Buffon refused intelligence to animals, they did so because they could not accord to them the same faculty of intelligence which characterises the human race. Their error therefore arose from not perceiving or not defining the limit which separates human from animal intelligence.

When Condillac and Leroy, on the contrary, falling into the other extreme, accorded to animals the most elevated intellectual powers, they did so because they overlooked the distinction between instinct and intelligence. When they ascribed to intelligence acts which were prompted by instinct, and therefore executed with a perfection which, if they were the result of intelligence, would require a very elevated degree of that faculty, they were forced to admit in animals the possession of powers in some respects even more elevated than those of the human race.

11. The first observations of Frederick Cuvier indicated the various degrees of intelligence in the different orders of mammifers. Thus he found the highest development of that faculty in the *Quadrumana*, at the head of which stand the chimpanzee and ourang-outang. The second rank was assigned to the *Carnivora*, at the head of which was placed the dog. The *Pachydermata* stand next, with the horse and the elephant at their head; the two lowest ranks consisting of the *Ruminants* and *Rodents*.

12. Now it is important to remark that this classification of mammifers according to their relative intelligence, based upon the direct observation of their manners and habits, is found to be in complete accordance with their cerebral development; the organs of the brain, which in man have been ascertained as being those on which the intellectual functions depend, existing in a less and less state of development as we descend from the Quadrumana to the Carnivora, from the latter to the Pachydermata, and from these successively to the Ruminants and Rodents.

* Descartes published his "Discours sur la Méthode" in 1637; and Buffon published the "Discours sur la Nature des Animaux" in 1753.

The reader will find these conclusions verified by many of the examples which will be presently produced, but those who desire a more complete demonstration must have recourse to the numerous and beautiful memoirs of Frederick Cuvier, in which the original observations are recorded.

13. After having established the limits which distinguish the degrees of intelligence of different orders of animals, Cuvier took up the still more important question to fix the limit between intelligence and instinct.

Between these powers there is the most complete opposition. All the results of instinct are blind, necessary, and invariable. All those of intelligence, on the contrary, are optional, conditional, and susceptible of endless modification. The beaver, which builds its hut, and the bird which constructs its nest, act by instinct alone. The dog and the horse, which are educated so as to understand the signification of several words uttered by those who have charge of them, do so by the exercise of intelligence.

All the results of instinct are innate. The beaver builds its hut without having learned to do so. It is urged by a constant and irresistible force. It builds because it cannot help building.

All the results of intelligence arise from experience and instruction. The dog obeys his master, only because he has learned to do so. He is a free agent, and obeys because he wills to obey.

In fine, the results of instinct are particular, while those of intelligence are general. The industry and ingenuity which has excited so much admiration in the beaver, is displayed in nothing except the construction of his hut, while the same degree of attention and thought, which enables the dog to obey his master in one thing, will equally avail him to perform other acts.

14. So long as these two powers of instinct and intelligence were undistinguished one from the other, the manners and habits of animals presented to the contemplation of the observer endless obscurity, and the most perplexing contradiction. While in most actions the superiority of man over other animals is apparent, in many the superiority seems to pass to the side of the brute. This paradox and apparent contradiction disappears, however, when the boundary between instinct and intelligence is clearly marked. Whatever proceeds from intelligence in the lower animals, is incomparably below that which results from the intelligence of man; and on the contrary, all those acts of the lower animals, which, supposing them to result from intelligence, would require a higher degree of that faculty than man possesses, are the mere effects of the blind mechanical power of instinct.*

* Flourens' "De l'Instinct et de l'Intelligence des Animaux," p. 36.

15. As an example of an act manifestly instinctive, a fact familiar to all who have visited a poultry-yard may be mentioned. When a mixed brood of chickens and ducklings hatched by a hen approach for the first time a pond of water, the ducklings precipitate themselves into the liquid, in spite of the efforts of their adopted mother to prevent them, and contrary to the example of the chickens, with whom they have come into life and from whom they have never been separated. The ducklings who do this may have never before seen water or any individuals of their own species, yet they use their webbed feet as propellers with as much skill as the oldest and most experienced of their race.

16. An example of a much more complicated process, which is manifestly instinctive, is presented by the labours of the bee already mentioned. The comb is a highly geometrical structure, which, if executed under the direction of intelligence, would require not only faculties of a high order, but profound calculation and much experience. Considered in relation to the purposes it is destined to fulfil, it would require the greatest foresight and a thorough knowledge of the whole course of life and organic functions of the species to which the constructors belong. Supposing them to be endowed with the necessary intelligence, the combs could not be constructed without many preliminary trials and partial failures, the necessary perfection being only attainable by slow degrees and by means of a series of experiments. Nothing of the kind however takes place, the complicated structure being produced at once with the greatest facility and in the highest perfection. There are, therefore, here none of the characters of a work directed by intelligence, but all the marks of one prompted by instinct.

17. Although the acts by which animals obtain and select their proper food are undoubtedly instinctive, they are, nevertheless, often attended with circumstances which it would be difficult to explain without the intervention of some degree of intelligence.

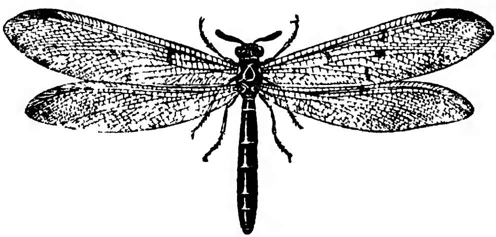


Fig. 1.—The Ant Lion.

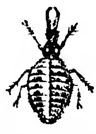


Fig. 2.—Larva of the Ant-Lion.

There is a little insect of the order *Neuroptera* and the family

Myrmeleonidæ, commonly called the *ant-lion*, represented in its natural size in fig. 1, the larva of which is also represented in its natural size in fig. 2. This larva feeds upon ants and other insects, of which it sucks the juice; but as its powers of locomotion are greatly inferior to those of its prey, it would perish for want of nourishment, if Nature had not endowed it with instinctive faculties by which it is enabled to capture by stratagem the animals upon which it feeds.

18. After having carefully surveyed the ground upon which it is about to operate, it commences by tracing a circle corresponding in magnitude with its intended snare. Then placing itself within this circle, and using one of its feet as a spade or shovel, it sets about making an excavation with a tunnel-shaped mouth. It throws upon its head the grains of sand which are digged up with its feet, and by a jerk of its body it flings them to a distance of some inches outside the circle which it has traced, throwing them backwards by a sudden upward movement of the head. Proceeding in this way it moves backwards, following a spiral course, continually approaching nearer to the centre. At length so much of the sand is thrown out that a conical pit is formed, in the bottom of which it conceals itself, its mandibles being the only parts which it allows to appear above the surface. If in the course of its work it happens to encounter a stone, the presence of which would spoil the form of the pitfall, it first pays no attention to it, and goes on with its labour. After having finished the excavation, however, it returns to the stone, and uses every effort to detach it, to place it on its back and throw it out of the pit. If it do not succeed it abandons the work, and departs in search of another locality, where it recommences with admirable patience a similar excavation.

These pitfalls, fig. 3, when completed, are generally about three inches in diameter and two in depth; and when the slope of the sides has been deranged, —which almost always happens when an insect falls into it,—the ant-lion immediately sets about repairing the damage.

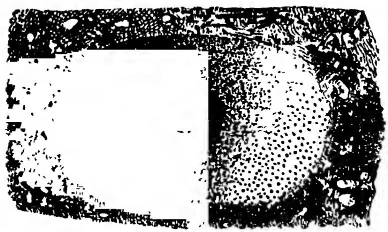


Fig. 3.—Pitfall of an Ant-Lion.

When an insect happens to fall into the pit, the ant-lion instantly seizes it and puts it to death, and the fluids having been all sucked out, its dry carcass is treated exactly like the grains of sand, and

jerked out of the hole. If, however, as often happens, an insect who has the misfortune to fall from the brink of the precipice should recover itself, and escaping the murderous jaws of its enemy regain the summit, the latter immediately begins to throw up more sand, whereby not only is the hole made deeper, but its sides are rendered more precipitous, and the flying insect is often hit by the masses thus projected, and brought down again to the bottom.

19. Certain spiders spread snares still more singular. The web which these animals spread is destined to catch the flies and other insects upon which they prey. The disposition of the filaments composing this web varies with different species, but is often of extreme elegance.

20. There are certain fishes which feed upon insects that are not inhabitants of the water, and who resort to expedients, bearing marks of great ingenuity, to capture their prey. Thus, a species called the *Archer*, which inhabits the Ganges, feeds on insects which are accustomed to light upon the leaves of aquatic plants. The fish, upon seeing them, projects drops of water upon them with such sure aim, that it seldom fails to make them fall from the leaf into the water, when it seizes upon them. As the near approach of the fish would alarm the insect and cause its flight, this species of liquid projectile is usually launched from a distance of several feet, where the insect cannot see its enemy.

21. Certain species feed upon natural products, which are only to be found at particular seasons of the year; and in all such cases Nature prompts them, during their proper harvest, to collect and store up such a quantity of food as may be sufficient for their support, until the ensuing season brings a fresh supply. The common squirrel (fig. 4.) presents an example of this instinct. During the summer these active little creatures collect a mass of nuts, acorns, almonds, and other similar products, and establish their storehouse usually in the cavity of a tree. They have the habit of providing several of these magazines

Fig. 4.—The Common Squirrel.

in different hiding-places cunningly selected; and in winter, when the scarce season arrives, they never fail to find their stores, even when they are overlaid with snow. It is remarkable that this impulse to hide their food does not cease with the necessity for it, for they take the same care of the residue unconsumed upon the return of the ensuing season.

22. Another rodent, called by naturalists the *Lagomys pica*, which bears a close resemblance to the common rabbit, and inhabits Siberia, is endowed with an instinct still more remarkable, since it not only collects in autumn the herbage necessary for its sustenance during the long winter of that inhospitable country, but it actually makes hay exactly as do our agriculturalists. Having cut the richest and most succulent herbs of the field, it spreads them out to dry in the sun; and this operation finished, it forms them into cocks or ricks, taking care so to place them that they shall be in shelter from the rain and snow. It then sets about excavating a tunnel leading from its own hole to the bottom of these ricks, so that it may have a subterranean communication between its dwelling and its hay-yard; taking care, moreover, that, the hay being gradually cut from the interior of each stack, the protection provided by the thatching of the external surface will not be disturbed.

23. Another form of that particular instinct the object of which is the preservation of the individual, is manifested in the art, with which certain species construct for themselves a suitable dwelling. In executing all the operations, often very complicated, directed to this purpose, their labours are invariably marked by the same general routine, although the operative by whom the work is executed has never before witnessed a similar process, and is aided by neither direction, plan, nor model.

We have already mentioned the structure of the honeycomb as an example of this, but the insect world abounds with others not less interesting.

The silkworm constructs for itself, with the delicate threads which it spins, a cocoon, in which it encloses itself, to undergo in safety its metamorphosis and to become a butterfly. The rabbit, in like manner, burrows for itself a dwelling, and the beaver constructs those little houses which have rendered it so celebrated. We shall, on another occasion, return to architectural instinct, in noticing the labours executed in common by animals which live in societies.

24. The hamster (fig. 5) is a little animal of the class of rodents, bearing a close resemblance to the common rat. It inhabits the fields throughout Europe and Asia, and inflicts much injury on the farmer and agriculturalist. This animal constructs for itself

a subterranean house, consisting of several rooms connected together by corridors. The dwelling has two communications with the surface, one consisting of a vertical shaft, by which the animal makes its entrances and exits; the other is an inclined shaft, merely used for the purposes of construction, the animal extruding through it the earth excavated in the formation of its habitation. One of the rooms is furnished, as the bedroom of the owner, with a couch of clean, dry grass, and is otherwise neatly kept. The others are used as store-rooms for the winter stock of provisions, which are amassed there in considerable quantities.

Fig. 5.—The Hamster.

The form of the store-rooms is nearly spherical, and their diameter from 8 to 10 inches.

The female, who never lodges with the male, usually provides several of these vertical entrances to her habitation, with a view to give easy means of entrance to her young, when they are pursued by any enemy, and obliged precipitately to take refuge in their dwelling.

The number of store-rooms which they provide being determined by their stock of provisions, they are excavated in succession, when one is filled the animal beginning to make another.

The room which the female constructs as a nursery for her young ones never includes provisions. She brings there straw and hay to make beds for them. Two or three times a year she has five or six younglings, which she nurses for about six weeks, at which age she banishes them from her dwelling to provide for themselves. The depth of the dwelling varies with the age of the animal, the youngest making it at about the depth of a foot. Each successive year the depth is increased, so that the vertical shaft leading to the den of the old hamster often has a depth of more than five feet, the whole habitation, including dwelling-rooms, store-rooms, and communicating corridors, occupying a space having a diameter of 10 or 12 feet.

25. Certain spiders, known to zoologists by the name of *mygales*, execute works similar to those of the hamster, but much more complicated, for not only do they construct a vast and commodious habitation, but they place at its entrance a *door*, mounted upon

hinges (fig. 6). For this purpose the animal excavates in the ground a sort of cylindrical shaft three or four inches deep, and coats its sides with a tenacious plaster. It then fabricates a door, by uniting alternately layers of plaster and vegetable filaments. This trap-door is made exactly to fit the mouth of the shaft, to which it is hinged by cementing some projecting filaments against the upper edge of the plastered surface. The external surface of this trap-door is rough, and in its general appearance differs little from the surrounding ground. The inside surface, however, is smooth and nicely finished. On the side opposite to the hinge there is a row of little holes, in which the animal introduces its claws to bolt the door when any external enemy seeks to force it open.

Fig. 6.—Nest of the Mygale.

26. It is, however, among the countless species of insects that we find the most curious and interesting processes adopted for the construction of habitations. Many species of caterpillars construct houses by rolling up leaves and tying them together by threads spun by the animal itself. In the gardens, nests of this kind are everywhere to be seen, attached to the leaves of flowers and bushes. It is in this way that the caterpillar of the nocturnal butterfly, the *Tortrix viridana*, forms its nest (fig. 7).

27. Other insects construct habitations for themselves with the filaments of woollen stuff, in which they gnaw holes. Among these is the well-known larva of the common moth, popularly miscalled a worm, which is found to be so destructive to articles of furniture and clothing. With the woolly filaments which it thus cuts from the cloth, the caterpillar constructs a tube or sheath, which it continually lengthens as it grows. When it finds itself becoming too bulky to be at ease in this dwelling, it cuts it open along the side, and inserts a piece, by which its capacity is increased.

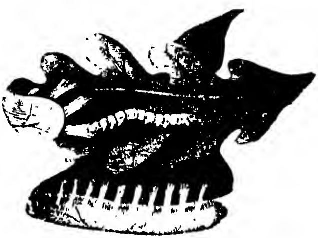


Fig. 7.—Nest of Tortrix Viridana.

28. Certain animals, which pass the cold season in a state of lethargy, not only prepare for themselves a suitable retreat, and a soft and comfortable bed, but when they become sensible of the

drowsiness which precedes the commencement of their periodical sleep, they take care to stop up the door of their house, as if they could foresee that a long interval must elapse before they shall want to go out, and that the open door would not only expose them to cold, but might give admission to dangerous enemies.

29. The alpine marmots supply examples of these curious manners.

These animals usually establish their dwellings upon the face of steep acclivities, which look to the south or the east; they assemble in large numbers for the excavation of these dwellings by their common labour. The form of their dens is that of the letter Y placed on its side, thus ≺, the tail being horizontal, and one of the two branches being inclined upwards, and the other downwards. The cavity, which forms the tail of the Y, is the dwelling-room. It is carpeted with moss and hay, of which the animal makes an ample provision in summer. The upward branch leads to the door of the dwelling, and supplies the means of exit and entrance to the inhabitants. The descending branch is used for the discharge of ordure, and all other offal, the removal of which is necessary to the cleanliness of the house.

30. Buffon says, that in the construction of these dwellings, the animals observe a curious division of labour: some cut the grass, others collect it in heaps, and others, lying on their backs with their legs upwards, convert themselves into a sort of sledge, upon which the grass is heaped by the others, being kept together by the upright legs of the prostrate animal, just as hay is retained upon a farm-cart by the poles fixed at its corners. The animal lying thus is dragged by the tail by the others, to the mouth of the dwelling in which the grass is deposited.

The latter part of this statement is however called in question by some naturalists.

31. The marmots pass the greater part of their lives in these dens. They remain there during the night and generally during bad weather, coming out only on fine days, and even then not departing far from their dwelling. While they are thus abroad feeding and playing upon the grass, one of the troop, posted on a neighbouring rock, is charged with the duty of a sentinel, observing carefully the surrounding country. If he should perceive approaching danger, such as a hunter, a dog, or a bird of prey, he immediately gives notice by a long continued whistling or hissing noise, upon which the whole troop instantly rush to their hole.

Fig. 9 – The White-throated Sapou.

32. There is another instinct worthy of notice, the object of which is always the preservation of the individual, and sometimes that of the species, which determines certain animals at particular epochs to undertake long voyages. These movements of migratory animals, as they are called, are sometimes periodic, being determined by the vicissitudes of the seasons, the animals being driven either from higher latitudes to lower by extreme cold, or from lower to higher by extreme heat. In other cases the migration is determined by the care of providing for its young; the animal migrating to localities where the food for its offspring abounds, and whence after depositing its eggs it departs

to places more conformable to its own habits and wants. Thus, the migration to and fro fulfils at once the double purpose of providing for the preservation of the species and that of the individual.

33. Where the migration is irregular, and the voyage not long, the movement is prompted by the necessity of seeking a locality where the proper nourishment of the animal is more abundant. In such cases, the animal having exhausted the supplies of a particular district, departs in quest of another, and does not voyage further than is necessary for that object.

Fig. 10.—The Maki.

34. Whatever be the motive which may prompt such voyages, they are almost invariably preceded by a general meeting, having all the appearance of a concerted one, composed of all the individuals of the species which inhabit the locality where it takes place. When the purpose of the voyage is change of climate, they do not wait until they are driven forth by an undue

temperature, but anticipate this change by an interval more or less considerable; nor do they, as might be supposed probable, suffer themselves to be driven by degrees, from place to place, by the gradually increasing inclemency of the season. It would appear that they consider such a frequent change of habitation incompatible with their well-being, and instead of a succession of short voyages, they make at once a long one, which takes them into a climate from which they will not have occasion to remove until the arrival of the opposite season.

35. The monkeys, which abound in such vast numbers in the forests of South America, present an example of irregular migration. When they have devastated a district, they are seen in numerous bands bounding from branch to branch, in quest of another locality more abundant in the fruits which nourish them: and after the lapse of another interval, they are again seen in motion, the mothers carrying the young upon their backs and in their arms, and the whole troop giving itself up to the most noisy demonstrations of joy.

Fig. 12.—Nest of the Goldfinch.

INSTINCT AND INTELLIGENCE.

CHAPTER II.

36. Migration of the lemmings.—37. Vast migration of field-mice of Kamtschatka.—38. Instincts conservative of species stronger than those conservative of individuals.—39, 40. Instincts of insects for the preservation of their posthumous offspring.—41. 42. Transformations of insects—Precautions in the depositions of eggs.—43. Habitation constructed by liparis chrysorrhea for its young.—44. Examples mentioned by Reaumur and Degeer.—45. Expedients for the exclusion of light from the young.—46. Example of the common white butterfly.—47. Manœuvres of the gadfly to get its eggs into the horse's stomach.—48. The ichneumon.—49. Its use in preventing the undue multiplication of certain species.—50. Its form and habits.—51. The nourishment of its larvæ.—52. The sexton beetle.—53. Their processes in burying carcasses.—54. Anecdote of them related by Strauss.—55. Singular anecdote of the gymnopleurus pilularius.—56. Such acts indicate reasoning.—57. Anecdote of a sphex told by Darwin.—58. Indications of intelligence in this case.—59. Anecdote of a sexton beetle related by Gleditsch.—60. Indications of reason in this case.—61. Anecdote of ants related by Reaumur.—62. Anecdote of ants related by Dr. Franklin.—63. Anecdote of the bee related by Mr. Wailes.—64. Anecdote of the humble bee by Huber.—65.

Memory of insects.—66. Recognition of home by the bee.—67. Singular conduct of the queen.—68. Rogers's lines on this subject.—69. Error of the poet.—70. Anecdote of bees by Mr. Stickney.—71. Instinct of the pompilides.—72. The carpenter bee.

36. IRREGULAR migrations, which are supposed to be in general determined by an instinctive presentiment of an approaching inclement season, are undertaken by small animals called lemmings, which have a close analogy to rats, and which inhabit

Fig. 11 —The Lemming.

the mountainous districts of Norway and the Frozen Ocean. These animals live in burrows, in which, like other similar species, they excavate rooms sufficiently spacious, in which they bring up their family. Their food consists in summer of herbs, and in winter of lichens. They lay up no store, however, and collect their supplies from day to day. By an inexplicable instinct, they have a foreknowledge of a rigorous winter, during which the frozen ground would not allow them to collect their food in the country they inhabit. In such case, they emigrate in immense numbers, going to more favoured climates. This surprising presentiment of the character of the season has been frequently observed in this species. It was especially noticed in 1742. During that winter the season was one of extraordinary severity in the province of Umea, though much more mild in that of Lula, of which nevertheless the latitude is higher. It was remarked, on this occasion, that the lemmings emigrated from the former province, but not from the latter.

On the occasions of such emigrations, countless numbers of troops of these animals, sometimes descending from the mountains, advance in close columns, always maintaining one direction, from which they never allow themselves to be turned by any obstacle, swimming across rivers wherever they encounter them, and skirting the rocks wherever they cannot climb over them. It is more especially during the night that these legions continue their march, reposing and feeding more generally during the day.

Although great numbers perish during the voyage, they nevertheless do immense damage to the districts over which they pass, destroying all the vegetation which lies in their way, and even turning up the ground, and consuming the fresh sown seed. Happily for the Lapland and Norwegian farmers, the visits of these animals are rare, seldom occurring more than once in ten years.

37. Such migrations, however, are much more frequently periodical, being determined, as already stated, by the change of seasons. Thus, it is found that in spring, immense legions of a little field-mouse, which inhabits Kamtschatka, depart from that country and direct their course towards the west. These animals, like the lemmings, proceeding constantly in one direction, travel for hundreds of leagues, and are so numerous that even after a journey of twenty-five degrees of longitude, in which a considerable proportion of their entire number must be lost, a single column often takes more than two hours to pass a given point. In the month of October they return to Kamtschatka, where their arrival constitutes a fête among the hunters, as they never fail to bring in their train a vast number of carnivorous animals, which supply furs in abundance to the inhabitants of these regions.

38. Nature seems even more sedulous for the preservation of the species than for that of the individual, and we find accordingly the instincts which are directed to the former purpose more strongly developed even than those of self-preservation. The animal world presents innumerable examples of this in the measures which nearly all species adopt with a view to the care of their young. The bird continues often for weeks to sacrifice all her own pleasures, and sits upon her eggs almost immovably. Before these eggs are laid she constructs with infinite labour and art a place in which she may with safety deposit them, and where the young which are destined to issue from them may be sheltered, protected, and fed by her until they have attained the growth and strength necessary to enable them to provide food and shelter for themselves.

39. The same instinct is manifested in a still more striking manner by insects. Many of these die immediately after they have laid their eggs, and consequently do not survive to see their young, of whose condition and wants therefore they can have no knowledge whatever by observation or experience. Their beneficent Maker has, however, taught them to provide as effectually for the security and well-being of their posthumous offspring, as if they had the most complete knowledge of their condition and wants. The effects of this instinct are so much the more remark-

able, as in many cases the young in their primitive state of larva inhabit an element and are nourished by substances totally different from those which are proper to their parent.

The instinct which guides certain animals to confer upon their young a sort of education, developing faculties and phenomena having a close analogy to those manifested in the conduct and operations of our own minds, never fails to excite as much astonishment as admiration, and teaches, more eloquently than words, how much above all that man can imagine or conceive, that power must be which has created so many wonders.

40. But the acts which manifest in the most striking manner the play of the instinctive faculty, are those already referred to by which insects, in the deposition of their eggs, adopt such precautions as are best calculated for the preservation of the young, which are destined to issue from these eggs when the provident mother is no more.

41. To comprehend fully this class of acts, it will be necessary to remind the reader that insects in general, before they attain their perfect state, pass through two preliminary stages, in which their habits, characters, and wants are totally different from those of the parent. The first stages into which the animal passes in emerging from the egg, is that of the *larva*, or grub; and the second, that of the *nymph*, or *pupa*.

Not only is the form and external organisation of the larva different from that of the insect into which it is destined to be ultimately transformed, but it is generally nourished by a different species of food, and often lives in a different element. Thus, while the perfect insect feeds upon vegetable juices, its larva is often voraciously carnivorous. While the perfect insect lives chiefly on the wing in the open air, the larva is sometimes aquatic, sometimes dwells on the hairs, or in the integuments, or even in the stomach or intestines of certain animals. The insect, therefore, cannot be imagined to know, from any experience, what will be the natural wants of the young which are destined to emerge from her eggs.

In many cases, any such knowledge on her part is still more inconceivable, inasmuch as the mother dies before her young break the shell. Nevertheless, in all cases, this mother, in the deposition of her eggs, is found to adopt all the measures which the most tender and provident solicitude for her young can suggest. If her young, for example, are aquatic, she deposits her eggs near the surface of water. If they are destined to feed upon the flesh or juices of any species of animal, she lays not only upon the particular animal in question, but precisely at those parts where the young shall be sure to find their proper nourishment.

If they are destined to feed upon vegetable substances, she deposits her eggs on the particular vegetables, and the particular parts of these vegetables which suit them. Thus, some insects lay their eggs upon the leaves of a certain tree, others in the bark of wood. Others again deposit them in the grain or seed of certain plants, and others in the kernel of certain fruits; each and all selecting precisely that which will afford suitable food to the larva when it breaks the shell.

42. But the care of the tender mother does not terminate here. As though she were aware that she will not herself be present to protect her offspring from the numerous enemies which will be ready to attack and devour it, she adopts the most ingenious expedients for its protection. With this view she envelops her eggs in coverings, which effectually conceal them from the view of the enemies to whose attack they would be exposed. In case the young should be susceptible of injury from the inclemency of the atmosphere, she wraps up the eggs in warm clothing, in which the young larva finds itself when it emerges from them.

43. Some species, such, for example, as the Liparis Chrysorrhea, envelop their eggs in a waterproof covering made of fur taken from their own bodies. They begin by forming with it a soft bed upon the surface of a branch, upon which they deposit several layers of eggs, which they then surround with more fur; and when all are laid, they cover them up with the same fur, the filaments of which, however, are differently disposed. The hairs which form the inside of the nest are arranged without much order, but, on the contrary, those which form its external covering are artfully arranged like the slates of a house, in such a manner that the rain which falls on them must glide off. When the mother has finished her work, which occupies her from twenty-four to forty-eight hours, her body, which before was invested with a clothing of rich velvet, is now altogether stripped, and she expires.

The females who thus provide for the protection of their young, often have the extremity of their bodies furnished with a great quantity of fur destined for this use.

44. Reaumur found one day a nest of this kind, but still more remarkable in its structure. The eggs were placed spirally round a branch, and covered with a thick and soft down, each hair of which was horizontal, which he described as resembling a fox's tail.

Degeer observed a proceeding, similar to those described above, with certain species of aphides, which cover their eggs with a cotton-like down, stripped from their own bodies by means of their hind-feet; but in this case the eggs were not enclosed in a common bed, but each in a separate covering.

45. These precautions seem to be intended not only to protect the eggs from wet and cold, but also to shade them from too strong a light, which would be fatal to the young they contain. It is doubtless for the same purpose that so many insects attach their eggs to the lower in preference to the upper surface of leaves, those which are placed on the upper surface being generally more or less opaque.*

46. The common white butterfly feeds upon the honey taken from the nectary of a flower, but her larva, less delicate and more voracious, devours the leaves of cabbage-plants. When we see, therefore, this insect flying about and alighting successively upon various plants, we imagine erroneously that she is in quest of her own food, when in reality she is searching for the plant whose leaves will form the proper nourishment for her future offspring. Having found this, and having carefully ascertained that it has not been pre-occupied by another of her species, she lays her eggs upon it and dies.

47. The young of the Gadfly (*Œstrus Equi*) are destined to live in the stomach of a horse. This being stated, it may well be asked how the insect fulfils that duty already described, which consists in depositing the eggs upon the very spot where the young will find their food; for it can scarcely be imagined that the winged insect will fly down a horse's throat to lay in its stomach. Yet the parent accomplishes its object in a manner truly remarkable. Flying round the animal, she lights successively many times upon its coat, depositing several hundreds of her little eggs at the extremity of the hairs, to which she glues them by a liquid cement secreted in her body. This, however, would obviously fail to accomplish the purpose of supplying the young with their proper food, only to be found in the horse's stomach, to which, therefore, it is indispensable that the eggs should be transferred. Marvellous to relate, this transfer is made by the horse himself, who, licking the parts of his hide to which the eggs are attached, takes them, or the grubs evolved from them, if they have been already hatched, upon his tongue, and swallows them mixed with saliva; thus conveying them to the only place where they can find their proper food!

But it may be objected, that by this process no eggs or grubs would find their way to the stomach, save those which might chance to be deposited upon those particular parts of the horse's body which it is accustomed to lick. There is, however, no chance in the affair; for the insect, guided by an unerring and beneficent power, and as if foreseeing the inevitable loss of such of

* Lacordaire, Int. Ent., vol i., p. 29.

her young as might be deposited elsewhere, takes care to lay her eggs on those spots only, such as the knees and shoulders, which the horse is sure to lick!

48. Ichneumon was a name given to a certain species of quadrupeds, which were erroneously supposed to deposit their young upon the bodies of crocodiles, the entrails of which they gradually devoured. The name was transferred by Linnæus to a vast tribe of insects, whose young are destined to feed upon the living bodies of other insects, on which accordingly the mother deposits her eggs. The ichneumons were called by some naturalists *Muscæ vibrantes*, from the constant vibration of their antennæ, by which they were supposed, in some unknown manner, to acquire a knowledge of the insects which would be fit food for their young. This supposition is, however, clearly erroneous, inasmuch as many species do not manifest this vibratory motion.

49. The ichneumons are agents of vast importance in the economy of nature, by checking the too rapid increase of certain species, such as the caterpillars of butterflies and moths, of which they destroy vast numbers. The purpose of nature in this is unmistakeably manifested by the fact, that the ichneumons increase in proportion to the increase of the species they are destined to destroy. Thus Nature maintains the equilibrium in the organic world as much by the operation of the destructive, as by that of the reproductive principle.

50. The ichneumon is a four-winged fly (fig. 12), which takes no other food than honey; and the great object of the female is to discover a proper nidus for her eggs. In search of this she is in constant motion. Is the caterpillar of a butterfly or moth the appropriate food for her young? You see her alight upon the plants where they are most usually to be met with, run quickly over them, carefully examining every leaf, and having found the unfortunate object of her search, inserts her sting into its flesh, and there deposits an egg. In vain her victim, as if conscious of its fate, writhes its body, spits out an acid fluid, menaces with its tentacula, or brings into action the other organs of defence with which it is provided. The active ichneumon braves every danger, and does not desist until her courage and address have insured subsistence for one of her future progeny. Perhaps, however, she discovers, by a sense, the existence of which we perceive, though we have no conception of its nature,

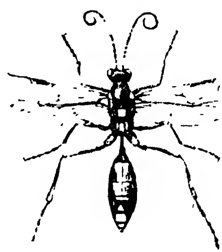


Fig. 12.—The Ichneumon.

that she has been forestalled by some precursor of her own tribe, that has already buried an egg in the caterpillar she is examining. In this case she leaves it, aware that it would not suffice for the support of two, and proceeds in search of some other yet unoccupied. The process is, of course, varied in the case of those minute species, of which several, sometimes as many as 150, can subsist on a single caterpillar. The ichneumon then repeats her operation, until she has darted into her victim the requisite number of eggs.

51. The larvæ hatched from the eggs thus ingeniously deposited, find a delicious banquet in the body of the caterpillar, which is sure eventually to fall a victim to their ravages. So accurately, however, is the supply of food proportioned to the demand, that this event does not take place until the young ichneumons have attained their full growth, when the caterpillar either dies, or, retaining just vitality enough to assume the pupa state, then finishes its existence; the pupa disclosing not a moth or a butterfly, but one or more full-grown ichneumons.

In this strange and apparently cruel operation one circumstance is truly remarkable. The larva of the ichneumon, though every day, perhaps for months, it gnaws the inside of the caterpillar, and though at last it has devoured almost every part of it except the skin and intestines, carefully all this time *avoids injuring the vital organs*, as if aware that its own existence depends on that of the insect on which it preys! Thus the caterpillar continues to eat, to digest, and to move, apparently little injured, to the last, and only perishes when the parasitic grub within it no longer requires its aid. What would be the impression which a similar instance amongst the race of quadrupeds would make upon us? If, for example, an animal—such as some impostors have pretended to carry within them—should be found to feed upon the inside of a dog, devouring only those parts not essential to life, while it cautiously left uninjured the heart, arteries, lungs, and intestines, should we not regard such an instance as a perfect prodigy, as an example of instinctive forbearance almost miraculous?*

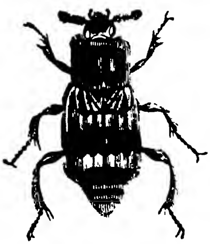


Fig. 13.—The Sexton-Beetle.

52. The sexton-beetle, or Necrophorus (fig. 13), when about to deposit its eggs, takes care to bury with them the carcass of a mole or some other small quadruped; so that the young, which, like the

* Kirby, Int., vol. i., p. 288.

parent, feed upon carrion, the moment they come into existence, may have an abundant provision of nourishment.

53. The measures which these insects take to obtain and keep the carcasses upon which they feed, and which, as has been just observed, also constitute the food of their offspring, are very remarkable. No sooner is the carcass of any small dead animal discovered, such as a bird, a mole, or a mouse, than the sexton-beetles make their appearance around it to the number generally of five or six. They first carefully inspect it on every side, apparently

Fig 14.—The Necrophorus Hydrophilus

Fig. 15.—The Marine Necrophorus.

for the purpose of ascertaining its dimensions, its position, and the nature of the ground on which it reposes. They then proceed to make an excavation under it, to accomplish which some partially raise the body, while others excavate the earth under the part thus elevated; the operation being performed with the fore legs. By the continuance of this process, going round the body, they gradually make a grave under it, into which it sinks; and so rapid is the process of excavation, that in a few hours the body is deposited in a hole ten or twelve inches deep. The males co-operate in this labour, and after it is accomplished, the female deposits her eggs upon the carcass.

54. Clarville * relates that he had seen one of these insects who desired thus to bury a dead mouse, but finding the ground upon which the carcass lay too hard to admit of excavation, it sought the nearest place where the soil was sufficiently loose for that purpose, and having made a grave of the necessary magnitude and depth, it returned to the carcase of the mouse, which it endeavoured to push towards the excavation; but finding its strength insufficient and its efforts fruitless, it flew away. After some time it returned accompanied by four other beetles, who assisted it in rolling the mouse to the grave prepared for it.

* Cited by Strauss, Considérations Générales, p. 389.

55. A similar anecdote is related of a sub-genus of the Lamellicornes, called the *Gymnopleurus pilularius*, an insect which deposits its eggs in little balls of dung. One of these having formed such a ball, was rolling it to a convenient place, when it fell into a hole. After many fruitless efforts to get it out, the insect ran to an adjacent heap of dung, where several of its fellows were assembled, three of whom it persuaded to accompany it to the place of the accident. The four uniting their efforts, succeeded in raising the ball from the hole, and the three friends returned to their dunghill to continue their labours.*

56. It is difficult, if indeed it be possible, to explain acts like these by mere instinct, without the admission of at least some degree of the reasoning faculty, and some mode of intercommunication serving the purpose of language. If such acts were common to the whole species and of frequent recurrence, it might be possible to conceive them the results of the blind impulses of instinct; but being exceptional, and the results of individual accident, they are deprived of all the characters with which by common consent instinct is invested. On the contrary, there are many circumstances connected with this, which indicate a surprising degree of reason and reflection. Thus, when the insect goes to seek for assistance, it does not bring back, as it might do, from the swarm engaged on the dunghill, an unnecessary number of assistants. It appears to have ascertained by its own fruitless efforts how many of its fellows would be sufficient to raise the dung-ball. To so many and no more it imparts its distress and communicates its wishes; and how can it accomplish this unless we admit the existence of some species of signs, by which these creatures communicate one with another?

57. Darwin relates, that walking one day in his garden, he perceived upon one of the walks a sphex, which had just seized a fly almost as large as itself. Being unable to carry off the body whole, it cut off with its mandibles the head and the abdomen, only retaining the trunk, to which the wings were attached. With these it flew away; but the wind acting upon the wings of the fly, caused the sphex which bore it to be whirled round, and obstructed its flight. Thereupon the sphex again alighted upon the walk, and deliberately cut off first one wing and then the other, and then resumed its flight, carrying off its prey.

58. The signs of intelligence as distinguished from instinct are here unequivocal. Instinct might have impelled the sphex to cut off the wings of the fly before attempting to carry it to its nest, supposing the wings not to be its proper food; and if the head

* Illiger's Entomological Magazine, vol. i., p. 488.

and abdomen of all flies captured and killed by the sphex were cut off, the act might be explained by instinct. But when the fly is small enough to allow the sphex to carry it off whole, it does so, and it is only when it is too bulky and heavy that the ends of the body are cut off, for the obvious purpose of lightening the load. With respect to the wings, the detaching them was an after-thought, and a measure not contemplated until the inconvenience produced by their presence was felt. But here a most singular effort of a faculty to which we can give no other name than that of reason, was manifested. The progress of the sphex through the air was obstructed by the resistance produced by the wings of the fly which it carried. How is it conceivable that upon finding this, and not before, the sphex should suspend its progress, lay down its load, and cut off the wings which produced this resistance, if it did not possess some faculty by which it was enabled to connect the wings in particular, rather than any other part of the mutilated body of the fly, with the resistance which it encountered, in the relation of cause and effect? To such a faculty I know no other name that can be given than that of reason, although I readily admit the difficulty of ascribing such an intellectual effort.

59. Gleditsch * relates that one of his friends desiring to dry the body of a toad, stuck it upon the end of a stick planted in the ground, to prevent it from being carried away by the sexton-beetle, which abounded in the place. This, however, was unavailing. The beetles having assembled round the stick, surveyed the object and tried the ground, deliberately applied themselves to make an excavation around the stick; and having undermined it, soon brought it to the ground, after which they not only buried the carcase of the toad, but also the stick itself.

60. Now this proceeding indicates a curious combination of circumstances which it appears impossible to explain without admitting the beetles to possess considerable reasoning power and even foresight. The expedient of undermining the stick can only be explained by their knowledge that it was supported in its upright position by the resistance of the earth in contact with it. They must have known, therefore, that by removing this support, the stick, and with it the toad, would fall. This being accomplished, it may be admitted that instinct would impel them to bury the toad, but assuredly no instinct could be imagined to compel them to bury the stick; an act which could be prompted by no conceivable motive except that of concealing from those

* Phys. Bot. Œcon. Abhand., vol. iii., 220.

who might attempt to save the body of the toad from the attacks of the beetles, the place where it was deposited.

61. Among the innumerable proofs that animals are capable of comparing, and to a certain extent generalising their ideas, so as to deduce from them at least their more immediate consequences, and thereby to use experience as a guide of conduct, instead of instinct, Reaumur * mentions the case of ants, which being established near a bee-hive, fond as they are of honey, never attempt to approach it so long as it is inhabited; but if they happen to be near a deserted hive, they eagerly rush into it, and devour all the honey which remains there. How can we account for this abstinence from the inhabited hive, in spite of the strong appetite for its contents, so plainly manifested in the case of the empty one, if not by the knowledge that on some former occasion a rash attack upon an inhabited hive was visited by some terrific vengeance on the part of the bees?

62. Dr. Franklin was of opinion that ants could communicate their ideas to each other; in proof of which he related to Kalm, the Swedish traveller, the following fact. Having placed a pot containing treacle in a closet infested with ants, these insects found their way into it, and were feasting very heartily when he discovered them. He then shook them out, and suspended the pot by a string from the ceiling. By chance one ant remained, which, after eating its fill, with some difficulty found its way up the string, and thence reaching the ceiling, escaped by the wall to its nest. In less than half an hour a great company of ants sallied out of their holes, climbed the wall, passed along ceiling, crept along the string into the pot, and began to eat again. This they continued to do until the treacle was all consumed, one swarm running up the string while another passed down. It seems indisputable that the one ant had in this instance conveyed news of the booty to his comrades, who would not otherwise have at once directed their steps in a body to the only accessible route.†

63. A similar example of knowledge gained by experience, in the case of the hive-bee, is related by Mr. Wailes.‡ He observed that all the bees, on their first visit to the blossoms of a passion-flower (*Passiflora cærulea*) on the wall of his house, were for a considerable time puzzled by the numerous overwrapping rays of the nectary, and only after many trials, sometimes lasting two or three minutes, succeeded in finding the shortest way to the honey at the bottom of the calyx; but experience having taught them

* Mémoires, vol. v., p. 709.
† Kirby and Spence, vol. ii., p. 422.
‡ Entomological Magazine, vol. i., p. 525.

this knowledge, they afterwards constantly proceeded at once to the most direct mode of obtaining the honey; so that he could always distinguish bees that had been old visitors of the flowers from new ones, the latter being at a loss how to proceed, while the former flew at once to their object.

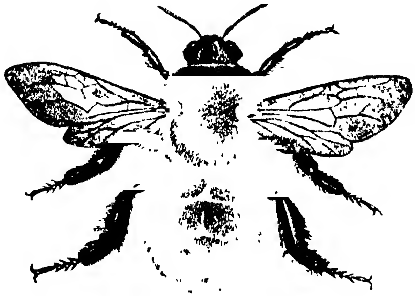


Fig. 16.—The Humble Bee

64. A similar fact is related of the humble bees by Huber,* who, when their bodies are too large to enter the corolla of a flower, cut a hole at its base with their mandibles, through which they insert the proboscis to extract the honey. If these insects adopted this expedient from the first, and invariably followed it, the act might be ascribed to instinct; but as they have recourse to it only after having vainly tried to introduce their body in the usual way into the opening of the corolla, it can scarcely be denied that they are guided by intelligence in the attainment of their end. The marks of experience, memory, and comparison, are unequivocal. When they find their efforts to enter the first flower to which they address themselves fruitless, they do not repeat them upon other flowers of the same sort, but directly attack the base of the corolla. Huber witnessed such proceedings repeatedly in the case of bean-blossoms.

65. Insects give proofs without number of the possession of the faculty of memory, without which it would be impossible to turn to account the results of experience. Thus, for example, each bee, on returning from its excursions, never fails to recognise its own hive, even though that hive should be surrounded by various others in all respects similar to it.

66. This recognition of home is so much the more marked by traces of intelligence rather than by those of instinct, inasmuch as it depends not on any character merely connected with the

* Philosophical Transactions, vol. vi., p. 222.

hive itself, whether external or internal, but from its relation to surrounding objects; just as we are guided to our own dwellings by the recollection of the particular features of the locality and neighbourhood. Nor is this faculty in the bee inferred from mere analogies; it has been established by direct experiment and observation. A hive being removed from a locality to which its inhabitants have become familiar, they are observed, upon the next day, before leaving for their usual labours, to fly around the hive in every direction, as if to observe the surrounding objects, and obtain a general acquaintance with their new neighbourhood.

67. The queen in like manner adopts the same precaution before she rises into the air, attended by her numerous admirers, for the purposes of fecundation.

68. This curious example of the memory of bees is beautifully noticed by Rogers, in his poem on that faculty.

"Hark! the bee winds her small but mellow horn,
Blithe to salute the sunny smile of morn.
O'er thymy downs she bends her busy course,
And many a stream allures her to its source.
'Tis noon, 'tis night. That eye so finely wrought,
Beyond the search of sense, the soar of thought,
Now vainly asks the scenes she left behind;
Its orb so full, its vision so confined!
Who guides the patient pilgrim to her cell?
Who bids her soul with conscious triumph swell?
With conscious truth retrace the mazy clue
Of varied scents that charmed her as she flew?
Hail, MEMORY, hail! thy universal reign
Guards the least link of Being's glorious chain."

69. The poet, however, has fallen into an error, as often happens when poets derive their illustrations from physical science. The bee is not reconducted to its habitation by retracing the scents of the flowers it has visited; for, if it were, it is obvious that in returning it would necessarily follow the zig-zag and tortuous course from flower to flower which it had followed during the progress of its labours in collecting the sweets with which it is loaded; whereas, on the contrary, in its return, no matter what be the distance, it flies in a direct line to its hive.

70. Kirby mentions the following curious fact illustrating the memory of bees, which was communicated to him by Mr. William Stickney, of Ridgemont, Holderness.

About twenty years ago, a swarm from one of this gentleman's hives took possession of an opening beneath the tiles of his house, whence, after remaining a few hours, they were dislodged and hived. For many subsequent years, when the hives descended from this stock were about to swarm, a considerable party of

scouts were observed for a few days before to be reconnoitring about the old hole under the tiles; and Mr. Stickney is persuaded that if suffered they would have established themselves there. He is certain that for eight years successively the descendants of the very stock that first took possession of the hole frequented it, as above stated, and *not* those of any other swarm; having constantly noticed them, and ascertained that they were bees from the original hive, by powdering them while about the tiles with yellow ochre, and watching their return. And even later there were still seen, every swarming season, about the tiles, bees which Mr. Stickney has no doubt were descendants from the original stock.

71. Among the instincts manifested by insects, there is none more remarkable or more admirable than that already mentioned, by which certain species provide a store of food for their young, which differs totally from their own aliment, and which they would themselves regard with disgust. The pompilides, a species resembling wasps, are endowed with this faculty. The insect in its adult state feeds, like the bee, upon floral juices. But its young, in the infant state of larva, is carnivorous. The provident mother, therefore, when she deposits her eggs, never fails to place beside each of them in the nest, in a place prepared to receive it, the carcase of a spider or of some caterpillar, which she has slain with her sting for that express purpose.

72. The carpenter bee presents another example of this remarkable instinct, boring with incredible labour in solid wood a habitation which, though altogether unsuitable to itself, is adapted with the most admirable fitness for its young. Among these, one of the most remarkable is the *Xylocopa violacea*, fig. 17, a large species,* a native of middle and southern Europe, distinguished by beautiful wings of a deep violet colour, and found commonly in gardens, where she makes her nest in the upright putrescent espaliers or vine-props, and occasionally in the garden-seats, doors, and window-shutters. In the beginning of spring, after repeated and careful surveys, she fixes upon a piece of wood suitable for her purpose, and with her strong mandibles

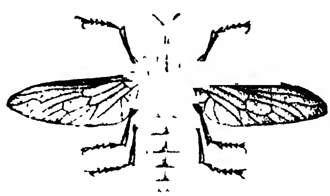


Fig 17.—The Carpenter Bee.

* Kirby, vol. i., p. 369.

begins the process of boring. First proceeding obliquely downwards, she soon points her course in a direction parallel with the sides of the wood, and at length, with unwearied exertion, forms a cylindrical hole or tunnel, not less than twelve or fifteen inches long and half an inch broad. Sometimes, where the diameter will admit of it, three or four of these pipes, nearly parallel with each other, are bored in the same piece.

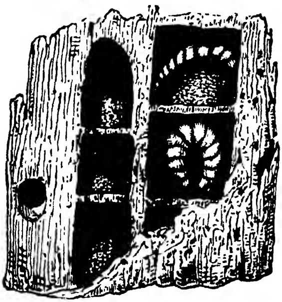


Fig. 18. Nest of the Carpenter Bee

Herculean as this task, which is the labour of several days, appears, it is but a small part of what our industrious bee cheerfully undertakes. As yet she has completed but the shell of the destined habitation of her offspring; each of which, to the number of ten or twelve, will require a separate and distinct apartment. How, you will ask, is she to form these? With what materials can she construct the floors and ceilings? Why, truly God "doth instruct her to discretion and doth teach her."

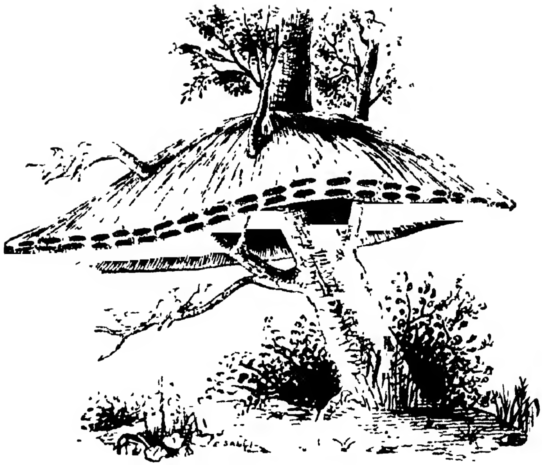


FIG. 2[illegible].—NESTS OF THE REPUBLICAN.

INSTINCT AND INTELLIGENCE.

CHAPTER III.

73. Habitations for the young provided more frequently than for the adults.—74. Birds' nests.—75. Nest of the baya.—76. Nest of the sylvia sutoria.—77. Anti-social instinct of carnivorous animals.—78. Their occasional association for predaceous excursions.—79. Assemblies of migratory animals.—80. Example of the migratory pigeons of America.—81. The beaver.—82. Their habitations.—83. Process of building their villages.—84. These acts all instinctive.—85. Low degree of intelligence of the beaver.—86. Method of catching the animal.—87. Social instinct of birds.—The republican.—88. Habitation of wasps.—89. Formation of the colony.—Birth of neuters.—90. Males and females.—91. Structure of the nest.—92. Form and structure of the comb.—93. Process of building the nest and constructing the combs.—94. Division of labour among the society.—95. Number and appropriation of the cells.—96. Doors of exit and entrance.—97. Avenue to the entrance.—98. Inferior animals not devoid of intelligence.—99. Examples of memory.—100. Memory of the elephant.—Anecdote.—101. Memory of fishes.—102. Examples of reasoning in the dog.—103. Singular anecdote of a watch-dog.—104. Low degree of intelligence of rodents and ruminants proved by Cuvier's observations.—105. Intelligence of the pachydermata—the elephant—the horse—the pig—the pecari—the wild boar.—106. The quadrumana.—107. Cuvier's observations on the ourang-outang—marks of his great intelligence.

In excavating her tunnel, the carpenter bee has detached a large quantity of fibres, which lie on the ground like a heap of sawdust. This material supplies all her wants. Having deposited an egg at the bottom of the cylinder along with the requisite store of pollen and honey, she next, at the height of about three-quarters of an inch (which is the depth of each cell), constructs of particles of the sawdust, glued together, and also to the sides of the tunnel, what may be called an annular stage or scaffolding. When this is sufficiently hardened, its interior edge affords support for a second ring of the same materials, and thus the ceiling is gradually formed of these concentric circles, till there remains only a small orifice in its centre, which is also closed with a circular mass of agglutinated particles of sawdust. When this partition, which serves as the ceiling of the first cell and the flooring of the second, is finished, it is about the thickness of a crown piece, and exhibits the appearance of as many concentric circles as the animal has made pauses in her labour. One cell being finished, she proceeds to another, which she furnishes and completes in the same manner, and so on until she has divided her whole tunnel into ten or twelve apartments.

When the work here described is considered, it is evident that its execution must require a long period of hard labour. The several cells must be cut out, their floors agglutinated, and they must be each supplied with a store of honey and pollen, the collection and accumulation of which is a labour which must occupy a considerable interval of time; and as the eggs are deposited successively in the cells according as they are finished and furnished, it is evident that they must be at any given moment in very different states of progress, the young issuing from those first deposited many days before the latest break the shell. But since there are ten or twelve such chambers vertically superposed, and since the lowest are the first laid, the new-born larva would either be condemned to be imprisoned in its cell until the births of all those above it should take place, or, in escaping to the exterior, it would have to pass through the chambers of all the others not yet developed, and would thus damage or destroy them. The beneficent Creator of the insect has, however, endowed it with an instinct which supplies the place of the foresight necessary to provide against such a catastrophe. With admirable forethought she constructs, besides the door already mentioned leading from cell to cell, another orifice in the lowest cell, which serves as a sort of postern, through which the insects produced from the earliest eggs emerge into day. In fact, all the young bees, even the uppermost, make their exit by this road; for each grub, when about to pass into the state of

pupa, places itself in its cell with its head downwards, and is thus necessitated, when arriving at the perfect state, to pass through the floor in that direction.*

73. It is especially in the first moment of their lives that animals in general are feeble, tender, and helpless, and have need of shelter from atmospheric vicissitudes, and protection from the attacks of their enemies; and we find, accordingly, that it is precisely these directions which have been given to the most irresistible instincts with which Almighty Goodness has endowed their parents. The number of species which in mature age build habitations for their own use, is insignificant compared with those which construct, with a labour which seems guided by the most touching tenderness and forethought, habitations for their young.

74. This habit is especially observable with birds. It is impossible to regard with sentiments other than those of the most profound interest the perseverance with which these creatures bring—straw by straw, and hair by hair—the materials destined for the formation of their nests, and the art with which they arrange them. The form, structure, and locality of these habitations is always the same for the same species, but different for different species, and are ever admirably adapted to the circumstances in which the young family are destined to live. Sometimes these cradles are constructed in the earth, and in a rude manner; sometimes they are cemented to the side of a rock, or to the wall of a building, but more commonly they are placed in the branches of trees, a hemispherical form being given to them (fig. 19.) They resemble, in form and structure, a little basket, rounded at the bottom and hollowed out at the top, the sides of which are formed of blades of grass, flexible straws and twigs, and hairs taken from the wool of animals, the inside being lined with moss or down.

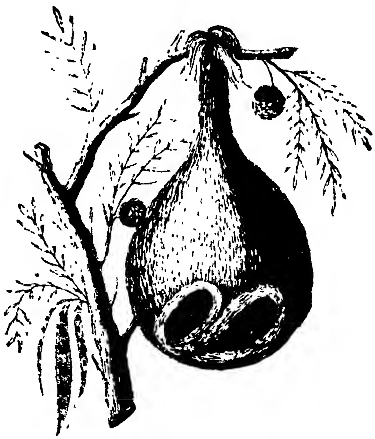


Fig 20.—Nest of the Baya

* Reaum. vi. 39—52; Mon. Ap. Angl. i. 189; Apis. * * a. 2. β.

75. Sometimes, however, a much more complicated and artificial structure is produced. The nest of the baya, a little bird of India, resembling the bullfinch, (fig. 20,) has the form of a flask, and is suspended from some branch which is so flexible that neither serpents, monkeys, nor squirrels can approach it. But still more effectually to secure the safety of their young, the mother places the door of the nest at the bottom, where it can only be reached by flying. This habitation would be liable to fall to pieces if it were formed of straws or filaments laid horizontally; it is, therefore, constructed with admirable skill of blades or filaments arranged longitudinally. Internally it is divided into several chambers, the principal of which is occupied by the mother sitting on her eggs; in another the father of the family is accommodated, who is assiduous in his attentions to his companion, and while she fulfils with exemplary tenderness her maternal duties he amuses her with his song.

76. Another oriental bird, called the sylvia sutoria, or sewing wood-bird, builds a nest equally curious. This little creature, collecting cotton from the cotton-tree, spins it with its bill and claws into threads, with which it sews leaves round its nest, so as to conceal its young from their enemies (fig. 21).

Fig. 21.—Nest of the Sylvia Sutoria.

77. Different species of animals are governed by social instincts which vary, but are always conducive either to the preservation or the well-being of the individual, or to the continuance of the race. When the food by which they are nourished is not so abundant as to support any considerable numbers in the same locality—which is generally the case with the larger species of carnivorous animals—they are endowed with an antisocial instinct, and not only lead a solitary life, but in many cases will not suffer any animal of their own species to remain in their neighbourhood.

78. Occasionally, however, the operation of this instinct is suspended. This takes place either when a scarcity of subsistence forces them to seek for food in places where they would be liable to attacks, against which their individual force would be insufficient for defence, or where some large flocks of animals of the sort on which they prey happen to come into their neighbourhood. In such cases they assemble by common consent in considerable numbers, and attack their prey in a body. Thus

we see in the winter season bands of wolves, impelled by hunger, descend from the hills or forests and ravage the stock of the farmer,—an enterprise on which they never venture when other food can be obtained at less risk. In such cases, however, when the immediate object of their enterprise has been accomplished, their antisocial instinct revives, and they disperse, often quarrelling among themselves.

79. Various species which do not habitually live in society, nevertheless assemble in vast numbers, when at certain seasons they make long journeys. This is the case generally with migratory animals. The social instinct is, however, only temporary, since, when the journey is completed, and they arrive at their destination, they disperse.

80. The migratory pigeons of North America present a remarkable example of this instinct, of temporary and periodical sociability. These birds, when stationary, are dispersed in vast numbers over the country, but when about to migrate, they assemble in inconceivable numbers, and perform their journey together, flying in a close and dense column nearly a mile in width, and six or eight miles in length. Wilson, the well-known American ornithologist, saw a flock of these birds pass over him in the state of Indiana, the number of which he estimated at two millions. The celebrated Audubon related that one day in autumn, having left his house at Henderson, on the banks of the Ohio, he was crossing an inclosed tract near Horsdensburgh, when he saw a flight of these pigeons, more than commonly numerous, directing their course from the north-west towards the south-east. As he approached Louisville, the flock became more and more numerous; he described its density and extent to be such, that the light of the sun at noon was intercepted, as it would have been by an eclipse, and that the dung fell in a thick shower like flakes of snow. Upon his arrival at Louisville, at sunset, having travelled fifty-five miles, the pigeons were still passing in dense files. In fine, this prodigious column continued to pass for three entire days, the whole population having risen and resorted to fire-arms to destroy them.

The usual habitations of these birds are the extensive woods which overspread that vast continent. A single flock will often occupy one entire forest; and when they remain there some time, their dung is deposited on the ground in a stratum several inches thick. The trees are stript throughout an extent of many thousand acres, and sometimes completely killed, so that the traces of their visit are not effaced for many years.

81. Of all mammifers, the Canadian beaver is the most remarkable for sociability, industry, and foresight. During the summer

it lives alone in burrows, which it excavates on the borders of lakes and rivers; but on the approach of winter, the animals quit these retreats, and assemble together for the purpose of constructing a common habitation for the winter season. It is in the most solitary places that they display their architectural instinct.

82. Two or three hundred having concerted together, select a lake or river too deep to be frozen to the bottom, for the establishment of their dwellings. They generally prefer a running stream to stagnant water, because of the advantage it affords them as a means of transport for the materials of their habitation. To keep the water at the desired depth, they commence by constructing a dam or weir in a curved form, the convexity being directed against the stream. This is constructed with twigs and branches, curiously interlaced, so as to form a sort of basket-work, the interstices being filled with gravel and mud, and the external surface plastered with a thick and solid coating of the same. This embankment, the width of which, at its base, is commonly from twelve to fourteen feet, lasts, when once constructed, from year to year, the same troop of beavers always returning to pass the winter under its shelter. Their labours after the first season are limited to keeping it in repair; they strengthen it from time to time by new works, and restore whatever may be worn away by the action of the weather. It is rendered more permanent by a vigorous vegetation, which soon clothes its surface.

83. Wherever stagnant water has been selected, this preliminary labour becomes unnecessary, and the animals proceed at once to build their village. But, as has been already observed, they are subject in that case to an equivalent amount of labour in the transport of the materials.

When this preliminary work has been completed, they resolve themselves into a certain number of families, and if the locality is a new one, each family sets about the construction of its huts; but if they return to the village they inhabited a former year, their labour is limited to the general repair and cleansing of the village.

The cabins composing it are erected against the dam, or upon the edge of the water, and generally have an oval form. Their internal diameter is six or seven feet, and their walls, like the dam, constructed of twigs and branches, are plastered on both sides with a thick coating of mud. The cabin, of which the foundation is below the surface of the water, consists of a basement and an upper storey, the latter being the habitation of the animals, and the former serving as storeroom for provisions.

The entrance to the cabin is in the basement story, and below the level of the water.

It has been supposed that the animal uses its tail as a trowel in building these habitations. It appears, however, that this is an

error, and that they use only their teeth and the paws of their fore-feet. They use their incisive teeth to cut the branches, and when necessary the trunks of trees; and it is with their mouth and their fore-feet that they drag these materials to the place where they intend to erect their habitation. When they have the advantage of running water, they take care to cut their wood at a point on the banks of the stream above the place where they are about to build. They then push the materials into the water, following and guiding them as they float down the stream, and landing them, in fine, at the point selected for their village. It is also with their feet that they excavate the foundations of their dwellings. These labours are executed with great rapidity and chiefly during the night.

84. The beaver, being a mammifer of the order of rodents, is one of the classes to which Cuvier assigns, as has been already stated, the lowest degree of intelligence. If the various acts here related were assigned to intelligence, they would evince a high degree of that faculty. Cuvier, however, demonstrated conclusively that they were acts altogether instinctive. He took several young beavers from their dams, and reared them altogether apart from their species, so that they had no means of acquiring any knowledge of the habits and manners of their kind. These animals, brought up in cages, isolated and solitary, where they had no natural necessity for building huts, nevertheless, pushed by the blind and mechanical force of instinct, availed themselves of materials, supplied to them for the purpose, to build huts.

85. In the low estimate of intelligence assigned by Cuvier to the beaver, other naturalists concur. "All agree," says Buffon, "that this animal, far from having an intelligence superior to others, as would necessarily be the case if his architectural skill were admitted to be the result of such a faculty, appears, on the contrary, to be below most others in its individual qualities. It is an animal, gentle, tranquil, familiar; of plaintive habits, without violent passions or strong appetites. When confined it is impatient to recover its liberty, gnawing from time to time the bars of its cage, but doing so without apparent rage or precipitation, and with the sole purpose of making an opening by which it may get out. It is indifferent; shows no disposition to attachment, and seeks neither to injure nor to please those around it. It seems made for neither obedience nor command, nor even to have commerce with its kind. The spirit of industry which it displays when assembled in troops, deserts it when solitary. It is deficient in cunning, without even enough of distrust to avoid the most obvious snares spread for it; and, far from attacking other animals, it has not the courage or skill to defend itself."

86. The pursuit of the beaver has been prosecuted to such an extent in Canada, that the animal has been nearly exterminated there, and more recently the trappers have been obliged to extend their excursions in search of them to the sources of the Arkansas, in the Rocky Mountains. The snare or trap used for catching the animal is similar to that used for foxes and polecats. The trappers, who make their excursions in caravans for mutual protection against the attacks of the Indians, acquire such skill, that they discern at a glance the track of the animal, and can even tell the number which occupy the hut. They then set their traps at a few inches below the surface of the water, and connect them by chains to the trunk of a tree, or to a stake planted strongly in the bank. The bait consists of a young twig of willow, stripped of its bark, the top rising to five or six inches above the surface of the water. The twig has been previously steeped in a sort of decoction made from the buds of poplar, mint, camphor, and sugar. The beaver, being gifted with a fine sense of smell, is attracted by the odour, and in touching the twig he disengages the detent of the trap and is caught.

87. The social instinct is not so common among birds as with mammifers, nevertheless some remarkable examples of it are found, among which may be mentioned a species of sparrow called the *republican*, which lives in numerous flocks in the neighbourhood of the Cape of Good Hope. These birds construct a roof (fig. 23), under which the whole colony build their nests.

88. But it is among insects we must look for the most striking manifestations of the architectural instinct.

The wasp (fig. 24.) affords an example of this, scarcely less interesting than the well-known economy of the bee. These little animals, though ferocious and cruel towards their fellow insects, are civilised and polished in their intercourse with each other, and compose a community whose architectural labours will not suffer by comparison even with those of the peaceful inhabitants of the hive. Like the latter, their efforts are directed to the erection of a structure for their beloved progeny, towards which they manifest the greatest tenderness and affection. They construct combs consisting of hexagonal cells for their reception; but the substance they use for this purpose is altogether different from wax, and their dwelling is laid out upon a plan in many respects different from that of the bee.

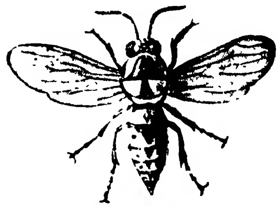


Fig. 24.—The Wasp.

89. Their community consists of males, females, and neuters. At the commencement of spring a pregnant female, which has survived the winter, commences the foundation of a colony destined before the autumn to become a population of some twenty or thirty thousand. The first offspring of this fruitful mother are the neuters, who immediately apply themselves to the task of constructing cells, and collecting food for the numerous members of the family who succeed them; and it is, while engaged in this labour, that they are most disposed to avenge themselves upon all who attempt to molest or interrupt them.

90. It is not till towards the autumn that the males and females are brought forth. The males as well as the neuter soon die, and the females surviving, seek some place of refuge in which to pass the winter, being previously impregnated.

91. The nest of the common wasp, generally built under ground, is of an oval form, from sixteen to eighteen inches high, and from twelve to thirteen in diameter.

Another species builds a nest of nearly the same form, but suspends it from the branches of trees; the size of these suspended nests varying from two inches to a foot in diameter. A section of the underground nest of a common wasp is shown in fig. 25.

It is a singular fact that the material of which the wasp builds its habitation is paper, an article fabricated by this insect ages before the method of making it was discovered by man.

With their strong mandibles they cut and tear from any pieces

of old wood to which they can find access, a quantity of the woody fibre, which they collect into a heap and moisten with

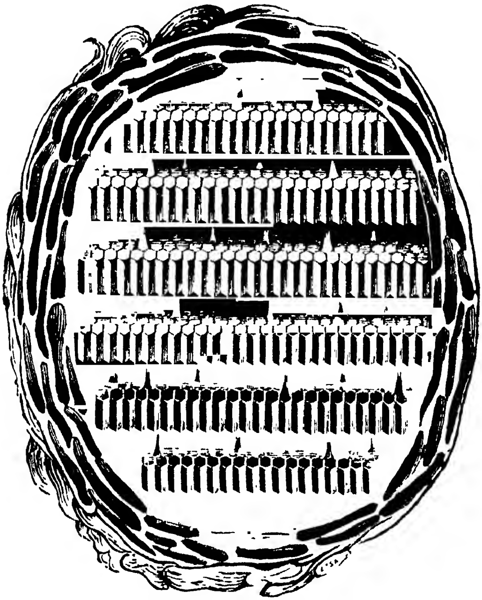


Fig. 25.—Underground Wasp's nest

viscid liquid secreted in their mouths. They knead this with their jaws until they form it into a mass of pulp similar precisely to that which the paper-maker produces from the vegetable fibre of linen or cotton rags. With this pulp, they fly off to their nests, where, by walking backwards and forwards, they spread it out into leaves of the necessary thinness by means of their jaws, tongue, and legs. This operation is repeated many times, until at length as much of the paper is produced as is sufficient to roof in the nest. The thinness of this wasp-made paper is about the same as that of the book now in the hands of the reader.

The coating of the nest consists of fifteen or sixteen leaves of this paper placed one outside the other, with small spaces between them as shown in the figure, so that if rain should chance to penetrate one or two of them, its progress may be arrested by the inner ones.

92. The interior of the nest consists of from twelve to fifteen horizontal layers of comb placed one over the other so as to form

as many distinct and parallel storeys. And here we may observe in passing, the difference between the architectural system of the wasp and that of the bee. The latter builds its cells in vertical strata ranged side by side, the mouths opening horizontally, so that the insects in passing between stratum and stratum must creep up the intervening vertical corridors; while the wasp, on the other hand, prefers horizontal corridors, so that in passing between stratum and stratum it creeps over one and under the other. In short, the positions given to the ranges of comb by the bee, in contradistinction to that adopted by the wasp, will be understood by supposing the sides of the wasp's habitation to represent the top and bottom of that of the bee.

Each comb of the wasp is composed, as shown in the figure, of a numerous assemblage of hexagonal cells made of the same paper as that already described, each cell being distinct, with double partition-walls. These cells, unlike those of the hive bee, are arranged only in a single row, the open end of each cell being turned downwards and the upper end being closed by a slightly convex lid, and not by a pyramidal cover like those of the honey-comb. The upper surface of each stratum of comb is therefore a continuous floor formed like an hexagonal mosaic, the surface being nearly but not perfectly smooth, since each hexagonal piece is curved slightly upwards.

The open mouths of the cells being presented downwards, the nurses as they creep along the roof of each stratum can easily feed the young grubs which occupy the cells of the stratum immediately above. The space left between one stratum and another is about half an inch.

Each stratum of comb is attached at the sides of the walls of the nest, but the tenacity of the paper of which the comb is composed would not be sufficient to sustain the weight of the stratum when the cells are all filled with grubs. The little architects, therefore, as though they had foreseen this, take care to connect at regulated intervals each stratum with that below it by strong cylindrical columns or pillars. Each of these, like the columns used in architecture, has a base and a capital, to which greater dimensions are given than those of the connecting shaft. These columns are composed of paper similar to that used for other parts of the nest, but of a more compact and stronger texture. The middle strata are connected by a colonnade of from forty to fifty of these pillars; the number being less as the dimensions of the strata decrease in going upwards or downwards.

93. The process of building this structure is as follows. The dome is first completed, as already described, by laying fifteen or

sixteen little sheets of paper one under the other, with intervening spaces at each part of it. Before the walls are further continued, the first or uppermost stratum of comb is then fabricated and attached to the sides by paper cement, and to the roof by a colonnade of pillars. The empty cells of this stratum being ready, the female big with eggs, deposits an egg in each, which is retained there by being agglutinated to the roof and sides of the cell: meanwhile, the workers continue their architectural labours, first carrying downwards the paper walls as already described, and next constructing the second stratum of comb and connecting it with the first by a colonnade.

94. It must be observed that in the society there is a well-organised division of labour. One part of it is employed exclusively in building, another in collecting food for the young, and in tending and nursing them, and, in fine, the female in depositing eggs in the cells. Since, therefore, a comparatively small proportion of the colony is engaged in building, the progress of the structure is necessarily slow, its entire completion being the work of several months; yet, though the result of such severe labour, it merely serves during the winter as the abode of a few benumbed females, and is entirely abandoned on the approach of the spring, wasps never using the same nest for more than a single season.*

95. The cells, which in a populous nest are not fewer than 16000, are of different sizes, corresponding to that of the three orders of individuals which compose the community; the largest for the grubs of females, the smallest for those of workers. The last always occupy an entire comb, while the cells of the males and females are often intermixed.

96. Besides openings which are left between the walls of the combs to admit of access from one to the other, there are at the bottom of each nest two holes, by one of which the wasps uniformly enter, and through the other issue from the nest, and thus avoid all confusion or interruption of their common labours.

97. As the nest is often a foot and a half under ground, it is requisite that a covered way should lead to its entrance. This is excavated by the wasps, who are excellent miners, and is often very long and tortuous, forming a beaten road to the subterraneous dwelling, well known to the inhabitants, though its entrance is concealed from incurious eyes. The cavity itself, which contains the nest, is either the abandoned habitation of moles or field mice, or a cavern purposely dug out by the wasps, which exert themselves with such industry as to accomplish the arduous undertaking in a few days.†

* Reaum. vi. 6.

† Kirby, vol. i. p. 426.

98. While it is incontestable that instinct is the predominant spring of action with the inferior species, it is nevertheless impossible to deny many animals the possession of a certain degree of intelligence. Many are evidently endowed, not only with memory, but even with judgment, and a certain degree of the reasoning faculty.

99. That many species possess the faculty of memory in a high degree of development is evident. Domesticated animals in general know and remember their homes and their owners. A horse, even after having made a single excursion from his stable, will recognise the road to it on his return, and it is even affirmed that upon returning after several years' absence to a locality which he has inhabited for a sufficient time to become familiar with it, he will again recognise it, and left to himself will find his way into the stable he formerly occupied, and resume the possession of his former stall. The dog, the elephant, and other domesticated animals, recognise, even after longer intervals, those who have treated them well or ill, and manifest accordingly their gratitude or their vengeance.

100. It happened not long since that an elephant in one of the collections publicly exhibited in this country, extending his trunk between the bars of his stall, suddenly struck down with it an individual among a crowd of spectators, obviously selected by the animal for the infliction of the blow. A circumstance so singular excited inquiry, more especially as it was seen that the person attacked had not in any way at the time offended or molested the animal. It was ascertained, however, upon inquiry, that some weeks previously the same individual had visited the menagerie, and had pricked the extremity of the trunk of the creature with some sharp instrument, taking care in doing so to be beyond its reach.

101. Even fishes do not appear to be altogether destitute of memory, since eels approach upon the call of their keeper. Serpents in menageries also manifest the same faculty.

102. The actions by which animals show the exercise of a certain degree of reasoning are scarcely less numerous. Thus, the dog, which is kept in a cage, will gnaw the bars if they are of wood, but will quietly resign himself to his captivity if they are of iron, because he understands that since he can make an impression on the bars in the first case by gnawing them, he may by continued efforts cut them through and effect his liberation; but finding the first efforts in the other case unavailing, he infers that their continuance could never accomplish his object.

When a dog sees his master put on his hat, the animal infers at once that he is going out, and jumping upon him loads him with

caresses to induce his master to take him as his companion. In this case there is reasoning, comparison, judgment, and a certain degree of generalisation. The dog *generalises* the act of putting on the hat, and *infers* its consequences, he *remembers* the act done on former occasions, and that it was followed by a walk abroad on the part of the master, and he *concludes* that what took place before will under like circumstances occur again.

103. A watch-dog, which was habitually chained to his box, found that his collar was large enough to allow him to withdraw his head from it at will. Reflecting, however, that if he practised this manœuvre when exposed to the observation of his master or keeper, the repetition of the act would be necessarily prevented by the tightening of the collar, he refrained from practising it by day, but availing himself of the expedient by night, roamed about the adjacent fields which were stocked with sheep and lambs, some of which, on these occasions, he would wound or kill. Bearing on his mouth the marks of his misdeeds, he would go to a neighbouring stream to wash off the blood, having done which he would return to his box before daybreak, and, slipping his head into the collar, lie down in his bed as though he had been there during the night.

104. In the series of observations and experiments by which F. Cuvier demonstrated the gradually increasing share of intelligence given to mammifers, proceeding from the lowest to the highest species, he showed from observations made on the habits and manners of marmots, beavers, squirrels, hares, &c., that rodents in general do not possess even that common degree of intelligence which would enable them in all cases to recognise their master or to know each other. The limited intelligence of the ruminants was shown in the case of a bison in the menagerie of the Garden of Plants, which having learned to recognise its keeper, ceased to know him when he changed his dress, and attacked him as it would have attacked a stranger. The keeper having resumed his original costume, was instantly recognised by the animal.

Two Barbary rams, which occupied the same stall, having been shorn, ceased to recognise each other, and immediately engaged in battle.

105. The manners of the elephant and horse are in obvious accordance with the rank assigned to them by Cuvier in the order of intelligence. But the pig species might seem at the first more doubtful. Nevertheless, Cuvier found that it was very little inferior to the elephant in sagacity. He found that the pecari, or South American hog, was as docile and familiar as the best trained dog. The wild boar is easily tamed,

recognises and obeys his keeper, and is capable of learning certain exercises.

106. The increasing degree of intelligence ascending from the Carnivora to the Quadrumana was clearly established by the observations of Cuvier, who found that in accordance with his system, the ourang-outang, of all mammifers, manifested the highest degree of intelligence.

107. A young ourang-outang, of the age of fifteen or sixteen months, was an especial object of observation and experiment. He showed the greatest desire for society, manifesting the strongest attachment for those who had charge of him. He loved to be caressed by them, and used not only to embrace, but even to kiss them. He pouted like a child when not allowed to have his way, and testified his vexation by cries, rolling himself on the ground, and striking his head upon it, so as to excite compassion by hurting himself.

This animal used to amuse itself by climbing up the trees in the Garden of Plants, and perching on their branches. It happened one day, that the keeper attempted to climb the tree to catch it. The ourang-outang immediately shook the tree with all its force, so as to deter the keeper from mounting it. The keeper then retired, and after an interval returned, approaching the tree, when the ourang-outang again set itself to shake the branches. "In whatever manner," says Cuvier, "this conduct may be viewed, it will be impossible not to see in it a combination of ideas, and to recognise in the animal capable of it the faculty of generalisation."

In fact, the ourang-outang in this case evidently reasoned by analogy from himself to others. He had already experienced the alarm excited in his own mind by the violent agitation of the bodies on which he was supported. He argued, therefore, from the fear which he felt himself to the fear which others would suffer in like circumstances. In other words, as Cuvier justly observes, he erected a general rule upon the basis of a particular circumstance.

This animal being one day shut up alone in a room, it availed itself of a chair which happened to be placed at the door, upon which it mounted to reach the latch. To prevent this manœuvre the keeper removed the chair; but the animal, when he had departed, seized another chair which was at a distance from the door, and placing it under the latch, mounted upon it in like manner.

In this case we find all the indications of memory, judgment, generalisation, and reasoning. The case is totally different from those so frequently witnessed in the case of animals trained for

exhibition. The animal had never been taught to mount upon a chair to reach the latch of the door, nor had he ever seen any one do so. It must therefore have been by his own experience alone that he learned to perform the act. By observing the actions of his keepers, he learned that chairs could be removed from one place to another. Generalising this, he inferred that he could remove a chair to the door. He learned also by his own experience, that by mounting on chairs and tables, he could reach objects which were unattainable from the floor, and, generalising this experience, inferred that he could by the same expedient reach the latch.*

It is impossible in cases like these to admit instinct as an explanation of the phenomenon. The circumstances under which such acts are performed, and the consequences which attend them, are incompatible with all the conditions usually attached to the faculty of instinct.

* Milne Edwards's Zoology, p. 256.

FIG. 27 —OURANG OUTANG.

INSTINCT AND INTELLIGENCE.

CHAPTER IV.

108. Anecdotes of the Ourang-Outang.—109. Analogy of the skeleton of the Ourang-Outang to that of Man.—110. Of the brain to the human brain.—111. Intelligence of the Wolf.—112. Anecdote of the Hawk, the Cat, the Eagle.—113. Of the Dog.—114. Of the Bear.—115. Intelligence of animals decreases with age.—116. Man distinguished from other animals by the degree of intelligence.—117. Lower animals are not endowed with reflection.—118. Inferior animals have methods of intercommunication as a substitute for language.—119. Examples in the cases of marmots, flamingoes, and swallows.—120. Intercommunication of ants.—121. Example in their mutual wars.—122. Acts which cannot be explained either by instinct or intelligence.—123. Carrier-pigeons.—124. Domesticity and tameness.

108. THE ourang-outang has been a subject of observation with all naturalists who have devoted their labours to the investigation of the habits of animals.

Buffon records circumstances respecting this animal that places him in close relation with man. Thus he has seen him present his hand to visitors to conduct them to the door, walk gravely with them as a friend or companion would, sit at table and spread his napkin in a proper manner, and wipe his lips with it, use a

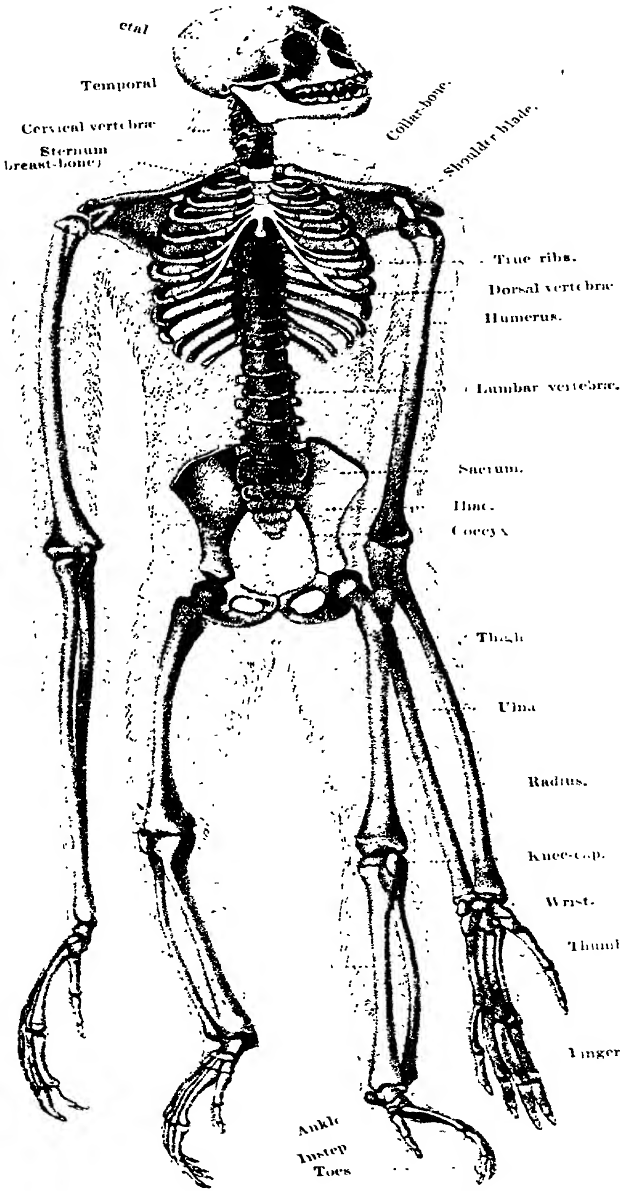


 Fig. 28.—Skeleton of Ourang-Outang.

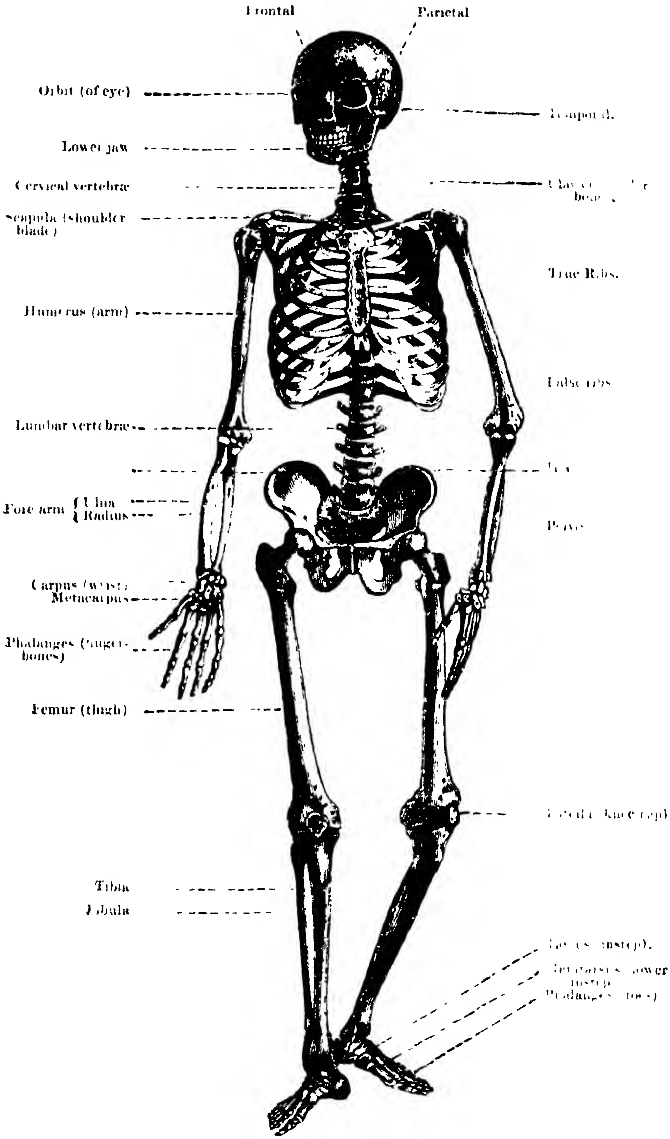


Fig. 2.—Human Skeleton.

M 2

spoon and fork to convey food to his mouth, pour wine into a glass and drink it, take wine with another at the table when so invited, clinking the glass according to the French custom; he would go and fetch a cup and saucer, put them on the table, put sugar in the cup, pour tea into it, and leave it to cool before drinking it, and all this without any prompting on the part of the master. He was circumspect in approaching persons, to avoid the appearance of rudeness, and used to present himself like a child desirous of receiving caresses.

M. Flourens found the same marks of intelligence in an ourang-outang in the Garden of Plants. This animal was gentle and sensible to caresses, especially from children, with whom he was always delighted to play.

He could lock and unlock the door of his room, and would look for the key of it. He showed none of the petulance and impatience common to apes. His air was serious, his gait grave, and his movements measured.

It appeared one day that an illustrious old savant accompanied M. Flourens to visit the animal. The figure and costume of this gentleman were singular. His body stooped, his gait was feeble, and movement slow. These peculiarities evidently attracted the notice of the animal. While he acquiesced with all that was desired of him, his eye was never withdrawn from his strange visitor. When they were about to retire, the animal, approaching the old gentleman, took with a certain expression of archness the cane from his hand, and affecting to support himself upon it, bent his back and hobbled round the room, imitating the gait and gestures of the stranger, after which, with the greatest gentleness, he returned to him the walking-cane.

"We quitted the ourang-outang," says M. Flourens, "convinced that philosophers are not the only observers in the world."

109. The close analogy of the structure of the ourang-outang to that of man will render this high degree of intelligence less surprising. This analogy is even more apparent in the skeleton than in the mere external form, as will be seen by comparing the fig. 28, which is that of the ourang-outang, with fig. 29, which is that of man.

110. An analogy not less striking is apparent in the brain of the animal compared with the human brain. In fig. 30 a side view of the human brain is presented, and in fig. 31 a similar view of the brain of the ourang-outang.

111. Leroy had already observed in the wolf, like signs of generalisation. When that animal appears, he is pursued, and the assemblage and tumult announce to him at once how much he is feared, and all that he has himself to dread. Hence, when-

ever the scent of man strikes his sense, it awakens in him the

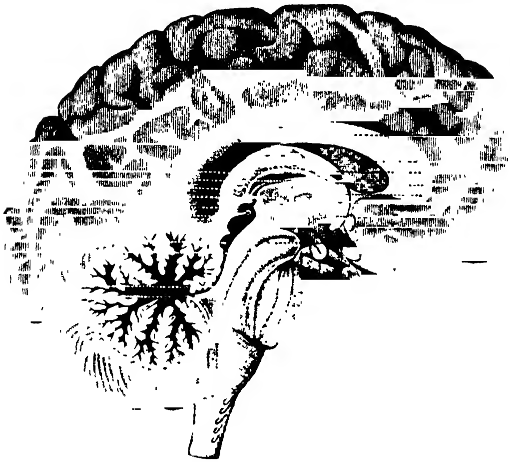


Fig. 30.—Human Brain.

idea of danger. While this fearful accessory attends it, the

Fig. 31.—Brain of the Ourang Outang.

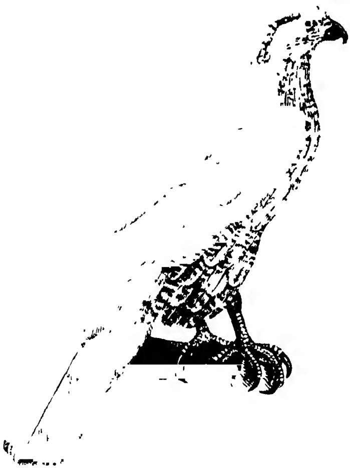
* This figure is slightly incorrect. The brain of the ourang does not quite overlay the cerebellum.

most seductive prey will not attract him; and even when the cause of danger is not present, the desired object is long regarded with suspicion. The wolf therefore, observes Leroy, must necessarily have an abstract idea of the danger, since he cannot be supposed to have a knowledge of the snares which are spread for him on any particular occasion.

112. The following curious anecdote of the habits of hawks and falcons is related by M. Dureau de la Malle.*

These birds, when they return from the pursuit of their prey

at the season when their younglings have become sufficiently fledged to rise on the wing, bring back in their talons some object, such as a mouse or sparrow, which they have killed, for the purpose of giving a lesson to their young in the art of capturing their prey. These birds are observed to have peculiar calls, which their young understand, and which are always repeated for the same purpose. M. de la Malle, who had a lodging in the Louvre, observed one day a male and female falcon thus returning and bringing with them a dead sparrow in their talons. They soared in the air over their nest, calling their younglings with the cry intended to summon them to rise on the wing. When the young birds thus rose, the old ones,



* Mémoire sur le dévellopement des facultés intellectuelles des Animaux.

soaring vertically over them, let fall the sparrow, upon which the younglings pounced. In the first attempts, the latter invariably failed in seizing the sparrow, not being yet sufficiently adroit. The old birds would then descend, and, seizing the prey rise with it into the air once more, and let it fall again upon the young; nor would they allow the latter to devour it until they succeeded in catching it as it fell.

These lessons were progressive. The prey first let fall on their younglings was dead. When they had acquired sufficient skill to seize this in falling through the air, the old parents brought living birds, first more or less disabled, and afterwards uninjured, upon which they exercised their young in the same manner; and this was continued until the young birds were fully able to pursue and seize their prey without further practice or instruction.

Every one has seen the cat give to her kittens similar progressive lessons.

She commences by biting a mouse so as to stun, or slightly disable, without killing it. She then liberates this mouse before her kittens, and encourages them to pursue it, the matron cat standing by, a vigilant observer of the scene. If the mouse shows any sign of escaping, she immediately pounces upon it, and disables it so effectually, that her kittens soon finish it.

According to Daubenton, the eagle carries its eaglet aloft upon its wings, and letting it go in mid air, tries its powers of flight. If its strength fails, the mother is sure to be at hand to support it.

113. Among the acts of animals which are obvious results of intelligence and not of instinct, the following may serve as instructive and interesting examples:—

Plutarch relates, that a dog desiring to drink the oil contained in a pitcher with a narrow mouth, the surface of the liquid being so low as to be out of the reach of his mouth, threw pebbles into it, which sinking in the oil, caused its surface to rise so high that the dog could lap it up. According to Plutarch, the dog must in this case have reasoned thus: the pebbles being heavier than the oil will sink to the bottom, they will displace part of the oil, and will displace more and more the more of them that are thrown in, therefore by throwing in a sufficient number, the surface of the oil must necessarily rise to the dog's mouth.

114. M. Flourens relates the following anecdote of bears in the Garden of Plants:—

It happened that these animals multiplied until there were more of them than it was desired to keep, and it was resolved to get rid of two. It was proposed to poison them with prussic acid. For this purpose some drops of that liquid were poured

upon little cakes, which being offered to the bears in the usual way, the animals stood up on their hind legs, and opened their mouths to catch them. The moment they received them, however, they spat them out, and retired to a remote corner of their den, as though they were frightened. After a short interval, however, they returned to the cakes, and pushed them with their paws into the water-trough left to supply them with drink, and there they carefully washed them by agitating them to and fro in the water. After this they smelled them, and again washed them, and continued this process until the poison was washed off, when they ate the cakes with impunity. All the poisoned cakes given to them were thus treated, while all the cakes not poisoned were devoured immediately.

The animals which had shown these singular marks of intelligence were spared the fate to which they had previously been condemned.

115. One of the most remarkable circumstances attending the faculty of intelligence, observed not only in the ourang-outang, but in all species of apes, is that its greatest development is manifested when the animal is young, and that instead of improving, it decreases rapidly with age. The ourang-outang when young excites surprise by his sagacity, cunning, and address. Having attained the adult state, he is a gross, brutal, and intractable animal.* In this, as well as in all other species of apes, the decrease of intelligence is commensurate with the increase of growth and strength. The intelligence of the animal, therefore, such as it is, is not like that of man, perfectable.

116. It is established, therefore, by the observations and researches of naturalists, that intelligence is a faculty common to man and to inferior animals. According to some, man is distinguished from other animals only by the degree in which he is endowed with this faculty; and the difference of degree is so immense, that, before accurate observations had proved the contrary, the faculty of intelligence was deemed the exclusive gift of the human race. Others contend that the intelligence of man differs from that of animals not in *degree* only, but in *kind;* that, in short, what is called intelligence in animals, is a faculty essentially different from what is called intelligence in man, and ought to have been called by a different name.

The intelligence of animals is limited and stationary. It is unimproveable and incommunicable. The intelligence of man, on the contrary, is susceptible of improvement without limit, and

* Flourens, "De l'Instinct et de l'Intelligence des Animaux," p. 35.

may be imparted from individual to individual. It radiates like light. Its power of growth and improvement is indefinite.

As we observed before, much of the obscurity and confusion which has attended all discussion respecting the intelligence of animals, arose from the omission of a sufficiently clear line of demarcation between instinct, properly so called, and intelligence.

The great purposes of instinct are the preservation of the individual and the continuance of the species. To plants, which live and die without change of place, the Creator has given strong and elastic tissues to ensure the preservation of the individual, and myriads of germs are put in immediate juxta-position with the organs destined to fecundate them, to ensure the continuance of the species.

To animals, which are endowed with powers of locomotion, and which are thereby exposed to numerous vicissitudes, God has given instinct to preserve the individual, to reproduce the species, and to perpetuate His work, thus rendering them unconscious agents in fulfilling His almighty command to "increase and multiply."

Instinct is then a gift emanating direct from divine goodness, and being a gift, and not a faculty, is inexplicable. It is a power inseparable from animal life. Its dictates are as imperious as those of gravitation or magnetism. It can neither be modified nor evaded. The bee constructs her comb in one manner and on one plan, from which no bee, old or young, ever departs. The bird builds its nest after a fashion as uniform, and by a law as rigorous, as that by which the lilies of the field put forth their blossoms.

Nor is man himself more emancipated from the sway of instinct. His first act on coming into the world is the instinctive seizure of the maternal nipple. Fear is the instinct of self-preservation; love that of the continuance of the species.

Intelligence on the one hand is the power of comprehending the consequences of acts, and of giving to them a direction determined by the will of the agent.

Reason is the most exalted form of intelligence, so exalted that some contend that it ought to be considered as a distinct faculty. It is by reason that man knows himself, judges himself, and conducts himself.

Animals are variously gifted with intelligence, for they are endowed with perception, memory, and consciousness. They are susceptible of passions and affections, not only physical, but moral. All the human passions, anger, hatred, jealousy and revenge, agitate them. They are devoted, affectionate, grateful, prudent, circumspect, and cunning. Kindness soothes and melts them. Injury awakens their resentment. The movements of the brain,

like those of the human encephalon, evokes in sleep their waking thoughts and desires. The dog of the chace dreams that he pursues the hare, and the more peaceful follower of the shepherd, that he collects the straying flock.

The intelligence of animals is rigorously limited to the objects of the external world that are presented to their senses. The intelligence of man has a far wider range. By the senses it is put in relation with the material world; by consciousness, with the inner being, the soul, and by intuitive ideas and sentiments with God.

The exalted intelligence of man confers on each individual a character as distinct as his features. He acquires from it his peculiar habits, qualities, tendencies, virtues, and faults. While it makes him free in one sense, it isolates him in another. Instinct, on the contrary, effaces individual distinction,—reducing all to a common type. All beavers, and all bees, lead lives absolutely alike, and may be regarded as differing no more than the units which make up an abstract number.

117. The inferior animals are endowed, as we have seen, largely with the powers of sensation, perception, and memory. They also possess, though in a very inferior degree, powers of comparison, generalisation, judgment, and foresight. In what then, it may be asked, consists the mark of the vast difference in degree of their intelligence, as compared with the mental powers exercised by the human race. This question has been satisfactorily answered by the observations and researches of Frederick Cuvier, Flourens, and others. According to these physiologists, animals receive by their senses impressions similar to those which are received by ours. Like us, also, they preserve and are able to recall the traces of these impressions. And such perceptions being thus preserved, supply for them as for us numerous and varied associations. Like us they combine them, observe their relations, and deduce conclusions from them, and to this extent, but not beyond it, their intelligence goes; but they have not a glimpse of that class of ideas which Locke denominates ideas of reflection. These, as is well known, are the perceptions which man acquires, not by his organs of sense, but by the power with which he is endowed to render his mind itself, and its operations, the subjects of contemplation and perception. Man has as clear a perception of the faculty of memory, for example, as he has of the colours of the rainbow. The scent of a rose is not more distinct to his apprehension than are his mental powers of comparison and induction. In short, his ideas of reflection are as vivid and definite as his ideas of sensation, and may, indeed, be said to be even more permanent and inseparable from his intellectual existence. He may be deprived of one or more of his

organs of sense, and thus cease to have any perception of the qualities peculiar to that organ, save those which his memory may supply. But so long as he exists and thinks, nothing can deprive him of the immediate perception of the ideas of reflection.

Of this class of ideas there is not the slightest trace in the inferior animals, and herein lies the line of demarcation which separates the human race from them, and places it immeasurably above them. Animal intelligence never contemplates itself, never sees itself, never knows itself. It is utterly incapable of that high faculty by which the mind of man, as Locke observes, "turns its view inward upon itself." That thought which contemplates itself; that intelligence which sees itself, and studies itself; that knowledge which knows itself, constitutes a distinct order of mental phenomena to which no inferior animal can attain. These constitute, so to speak, the purely intellectual world; and to man alone, here below, that world belongs. In a word, the animals feel, know, and think: but to man alone of all created beings it is given to feel that he feels, to know that he knows, and to think that he thinks.

118. Of all the instruments by which the range of intelligence is enlarged, and the power of reason augmented, language is assuredly the most important. It is the means by which feelings are expressed and knowledge imparted. It is the instrument by which the observation and experience of individuals is rendered common property.

Language, in the only sense in which it is an instrument of intelligence, is not the mere mechanical production of distinct sounds by the vocal organs, for in this sense parrots may be said to be endowed with it. It is a divine gift and not a faculty. Its origin has been sought for by the learned, but sought in vain. Like the instinct of self-preservation and reproduction, it has been an immediate emanation of divine power. God made it as he made light. He said, "Let man speak," and man spoke!

Most animals have voice, but man alone has language. It is by language, more than any other external character, that man is distinguished. The animals which come nearest to him in their physical organisation, such as the ourang-outang and other apes, are as completely deprived of language as those which are most removed from him. Man is thus separated from the lower animals by a bottomless abyss.

So important is language, as a means of extending the intelligence, that in a moral sense it may be said, that to speak or not to speak, is to be or not to be!

There can be no doubt in the mind of any careful observer, that

the chief obstacle to the extension of the natural intelligence of many animals is the want of language to express their feelings and thoughts. It is evident that if the dog or the ourang-outang, which was the subject of Cuvier's experiments, could speak, their intelligence would be vastly enlarged.

Deprived of language, the more intelligent of the inferior animals seem, like the dumb, deeply conscious of the want, and make supernatural efforts to supply it and to make their sentiments understood. For this purpose they resort to ingeniously modulated vocal sounds, to signs and gestures. Each creature invents for itself a sort of pantomimic and highly expressive language. The dog appeals to you by gently laying his paw upon you, and if that fail to awaken your attention, he strokes you or taps you with it, as if he knew that you would thus be more apt to *feel* his solicitation. Does the cat desire to have some want supplied? she raises her back and passes her soft fur in contact with your legs, and repeats the application by going round and round you. The horse waiting at your door, fresh from his stall, and impatient for air and exercise, expresses his desire by pawing the ground with his fore-foot. In the pairing season, the male bird tries to fascinate his gentle mate by spreading out the fine hues of his plumage, making circuits, and fluttering around her.

All animals that have voice at all, use its modulations as a means of expression, and render it manifest that they would speak if they could. Many and ingenious are the artifices which they use as a substitute for the admirable instrument of intercommunication with which man has been gifted.

119. Thus, for example, in the case of such mammifers and birds as usually assemble in herds or flocks, individuals are observed who, being placed as sentinels, warn their companions of the approach of danger.

Marmots and flamingoes present examples of this. It is also observed with swallows, who, when their young are menaced by an enemy, immediately call together, by their cries of distress, all the swallows of the neighbourhood, who fly to the aid of their fellows, and unite to harass the animal whose attack they fear.

120. It has been well ascertained that various species of insects have means of intercommunication. The observations of Huber, Latreille, and other naturalists, leave scarcely a doubt on this point. Thus, for example, when an ant's nest has suffered any local disturbance, the whole colony is informed of the disaster with astonishing rapidity; no appreciable sound is heard, but the particular ants who are witnesses of the fact, are seen running in various directions among their companions. They bring their heads into contact, and unite their antennæ as two persons

would who take each other by the hand. All the ants who are thus addressed are immediately observed to change their route if they were moving, and to abandon their occupation if they were at work, and to return with those from whom they received the information, to the scene of the disaster, which is soon surrounded by thousands of these insects, thus brought from a distance.

121. In the wars which the population of two neighbouring ant-hills wage with each other, scouts and outposts precede the main body of the enemy, who often return to the leaders, giving them information, the consequence of which is, a total change in the order of march. In cases where these conflicts become doubtful, and that an army finds itself in danger of defeat, the leaders are often seen to detach aides-de-camp, or orderly officers, who return in all haste to their ant-hill, to bring up reinforcements, which assemble without delay, and march to join the main body of the army.

122. Large as the range of action is, which admits of explanation either by intelligence or instinct, or by the combination of both these faculties, some acts still remain of an extraordinary character which cannot be thus explained, and which would seem to imply the existence of some faculty in certain species of inferior animals of which man is totally destitute.

123. Among these may be mentioned the curious power with which certain birds, such as pigeons and swallows, are endowed; who, after being transported in close boxes to many hundred miles from their nest, take flight upon being liberated, and without the least hesitation direct their course towards the place from which they had been taken, with a precision as unerring as if it were actually within their view. In the case of dogs, and other mammifers, who having been brought to a great distance from home find their way back, the act is explained by the extreme delicacy of their sense of smell; but no such explanation will be admissible in the case of carrier-pigeons, who, having been brought, for example, from London to Berlin, and being liberated at the latter city, instantly direct their course back to the former, flying over the great circle of the earth which joins the two places. We are not aware that any attempt has been made to refer this class of facts to any recognised faculty.

124. Closely connected with instinct and intelligence is the capability of animals to be tamed and domesticated.

Naturalists agree generally that the animals which are domesticated with greatest facility are those which in the wild state live in troops or societies. To this there is scarcely a well-established exception. The cat and the pig are apparent exceptions,

and more necessary by the benefits he confers; and having arrived at that point, he ventures to employ fear and chastisement, which if resorted to without the previous measures would have excited resistance and repugnance.

To tame an animal is not to train him. Tameness is the subjugation of those instincts which would render him hurtful to those around him. Training is directed to the intelligence rather than the instinct. It is an educational process, which develops intelligence while it weakens instinct. Savages, while they are less intelligent than the civilised, have surer and quicker instincts. It is the same with the lower animals. Domesticity always enfeebles and often wholly effaces instinct.

When man educates and trains an animal, he imparts to it a ray of his own intelligence. The change is rather that of a new faculty created than of an existing one enlarged. It is a transformation rather than an improvement.

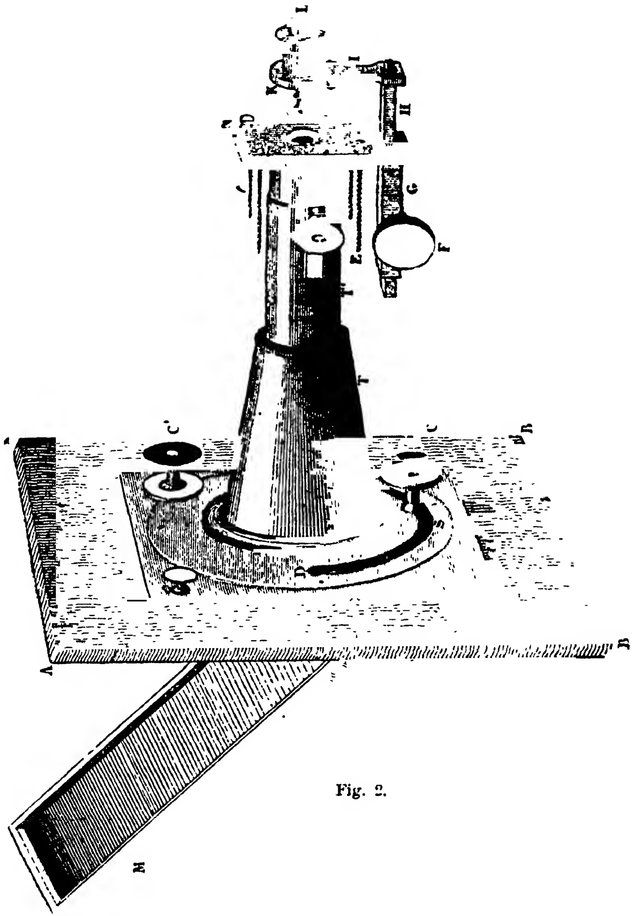


Fig. 2.

THE SOLAR MICROSCOPE.

1. Its utility.—2. The principle of its performance.—3. Why the magic lantern does not serve the same purposes.—4. The illuminating apparatus. — 5. How to protect the object from heat. — 6. The amplifying apparatus.—7. The adjustments.—8. The screen.—9. The reflector.—10. Method of mounting the instrument.—11. Arrangements for the room of exhibition.—12. Preliminary adjustments. —13. The oxy-hydrogen and electric microscopes.

1. As an instrument for popular and general instruction, the solar microscope holds a high place. Until recently, its use has been restricted in these climates, by the circumstance of bright sunshine, and a room having a suitable aspect, being conditions indispensable for its performance. But by the substitution of the oxy-hydrogen light, and more recently still, of the electric light, the utility and pleasure derivable from this instrument of popular illustration have been immensely extended.

2. The principle of the solar microscope is the same as that of the magic lantern, and we must, therefore, refer the reader to our Tract upon that subject, for many details, to save the necessity of their repetition. The instrument consists of two parts, essentially distinct one from the other: the first, the illuminating; and the second, the magnifying part. Since it is desired to exhibit a very enlarged optical image of a very minute object, and since the light which is spread over the image can only be that which falls on the object, it is evident, that the brightness of the image will be more faint than that of the object, in the exact proportion in which the surface of the former is greater than that of the latter. To illustrate this, let us suppose that the object exhibited is an insect, a quarter of an inch in length, and that it is magnified 40 times in its linear dimensions, the length of the optical image will then be 10 inches, and its surface will be 1600 times greater than that of the object. The light, therefore, which illuminates the object, supposing the whole of it to be transmitted to the optical image, being diffused over a surface 1600 times greater, will be 1600 times more faint. But, in fact, the whole of the light never is transmitted, a considerable part of it being lost in various ways in passing from the object to the screen. The necessity, therefore, for very intense illumination in this instrument must be evident.

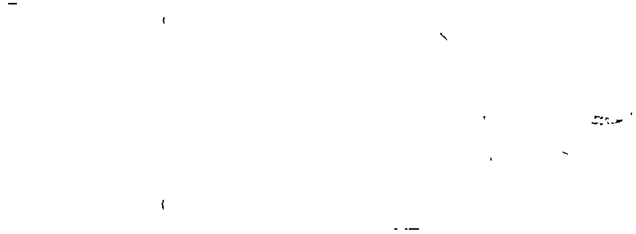
3. If these conditions were not borne in mind, it might appear that a magic lantern might be converted into such a microscope, by merely increasing the magnifying power of the lenses; but the light of the lamp, which is sufficient to illuminate a picture magnified 10 or 12 times in its linear, and, therefore, from 100 to 144 times in its superficial dimensions, would be utterly insufficient, if it were rendered 1600 times more feeble.

4. The illuminating apparatus of the solar microscope consists of a large convex lens, upon which a cylindrical sunbeam of equal diameter is projected. This lens causes the rays of such a sunbeam to converge to a point, and they are received upon the object to be exhibited before their convergence to a focus, and at such a distance from the focus, that the entire object shall be illuminated by them. In fact, the rays may be considered as forming a cone

which is cut at right angles to its axis by the slider upon which the object is fixed.

Let C C, fig. 1, be the condensing lens; let F be the focus to which the rays would be made to converge, but being intercepted

Fig. 1.



by the slider S S, they are collected upon the small circular opening O O in the slider, and in this circular opening the small microscopic object to be exhibited is mounted between two thin plates of glass.

Now, it is evident, that the intensity of the light thus projected upon the object will be greater than that with which it would be illuminated without the interposition of the lens C C, in the exact proportion of the surface of the lens C C to the surface of the circular opening O O. Thus, for example, if the diameter of the lens C C be 5 inches, and the diameter of the opening O O half an inch, the diameter of the lens will be 10 times, and, therefore, its surface 100 times greater than that of the opening O O. In that case the object would be illuminated with a light just 100 times more brilliant than if the sun's light fell directly upon it, without passing through the lens C C.

It is found convenient in some cases to condense the light by means of two lenses. The cone of rays proceeding from C C might be received upon another condensing lens, by which its convergence might be increased. The advantage of this arrangement is that the distance of the object from C C, and therefore the length of the microscope, is rendered less than it otherwise would be.

5. There is, however, one practical inconvenience to be guarded against in this arrangement. The lens C C, which condenses the sun's light upon the object, also condenses its heat, and if the same object be exposed in the instrument for any considerable time, it would thus be injured or destroyed. This inconvenience may be obviated by the interposition of certain media, which, while they are pervious to the sun's light, are impervious to its heat; such media are said to be athermanous.*

* From the Greek negative α (a) and θέρμη (thĕrmè) heat.

By the interposition of such a medium, the object may be prevented from receiving any increased temperature whatever.

It happens that water, which is the most convenient medium for this purpose, is very imperfectly pervious to heat, and is rendered almost completely athermanous by dissolving in it as much alum as it is capable of holding in solution. The object, therefore, is perfectly protected from the effects of heat, by placing between the slider and the condensing lens a cell, consisting of two parallel plates of glass, fixed at about an inch asunder, and filled with such a saturated solution of alum. The light intercepted by this is altogether inconsiderable, while the whole of the heat is stopped by it.

6. The magnifying part of the solar microscope consists of an achromatic lens, or combination of lenses, of very short focal length; this being brought before the object, at a distance from it a little greater than its focal length, will produce a highly magnified optical image of the object, upon a screen placed at a proper distance before it.

In the case of the magic lantern, it is not indispensable to incur the expense of achromatic lenses, and even the expedients to correct the spherical aberration are but little attended to. The magnifying powers used in that instrument not being great, and the objects exhibited not requiring extreme accuracy of delineation, the expense which would be incurred in producing large lenses free from the aberrations is not necessary. But in the case of microscopic objects, where great magnifying powers are applied, lenses in which the aberrations are not corrected would produce images so confused and indistinct as to be altogether useless. Achromatic combinations, therefore, in which the spherical aberrations are also corrected, are in this case indispensable.

As in the magic lantern, the same lenses may be applied, so as to produce different magnifying effects. If the distance of the lenses from the object were so great as twice their focal length, the image would be projected upon the screen at a distance in front of the lens also equal to twice its focal length, and would in that case be exactly equal to the object, and consequently there would be no amplification at all. As the lenses, however, are moved nearer to the object, the distance at which the image would be formed and its magnitude would be increased, and this increase would go on without practical limit, until the distance of the lens from the object would become equal to its focal length, in which case the image, having been enlarged beyond bounds, would altogether disappear.

In practice, therefore, the focus of the lens is brought to such a distance from the object, that the image upon the screen shall have a magnitude sufficient for all the purposes of exhibition. It

is not desirable, however, in any case, to push the amplifying power of the instrument too far, because the illumination of the image in that case becomes inconveniently faint; and if there be any causes of aberration uncorrected in the lenses, whether spherical or chromatic, their effects will be rendered more apparent.

7. In the mounting of the instrument, provisions are necessary for varying, within certain limits, the distance of the object, as well from the illuminating as from the amplifying lenses. If the object be very minute, it is necessary that it should be illuminated with proportionate intensity; and, therefore, that it should be moved very near to the focus of the illuminating lens, C C. If it be larger, this position would, however, be unsuitable, inasmuch as the light would be collected upon a small part of it, to the exclusion of the remainder. In that case, therefore, the object must be brought farther in advance of the focus, F, of the illuminating lens, so as to intersect the cone at a point of greater section, and thus to receive a light which, though less intense, will be diffused over its entire surface.

The amplification required will be greater in proportion as the object is smaller. For very minute objects, therefore, the amplifying lens must be brought nearer to the object, and the screen must be removed farther from it, while for larger objects, the arrangement would be the reverse.

8. All that has been said on the subject of the screen in the case of the magic lantern will be applicable to the solar microscope, except that, in this case, the method of showing the object through a transparent screen is objectionable, because of the light which is lost by it, and for other reasons; and, besides, it is useless, that method of exhibition being adapted only for phantasmagoria, and other similar subjects of amusement.

9. In what has been explained above, it has been assumed that a beam of solar light is thrown upon the condensing lens C C, in the direction of its axis. Now it is evident that it could never happen that the natural direction of the sun's rays would coincide with that of the axis of the tube of the microscope; for, that axis being necessarily horizontal, or nearly so, the sun to throw its rays parallel to it should be in the horizon. Some expedient, therefore, is necessary, by which the direction of a sunbeam can be changed at will, and thrown along the axis of the tube.

The obvious method of accomplishing this is by means of a plate of common looking-glass; such a plate being conveniently mounted in front of the condensing lens, may always have such a position given to it that it will reflect the sunbeam which will fall upon it in the direction of the axis of the tube.

But since, by reason of its diurnal motion, the sun changes its

position in the heavens from minute to minute, the position of the reflector, which at one time would throw the light in the proper direction, would cease to do so after the lapse of a short interval. A proper provision must be made, therefore, by which the position of the reflector may be changed from time to time with the motion of the sun in the firmament, so that it shall always reflect the light in a proper direction.

10. A perspective view of the solar microscope, mounted in the most efficient manner, is given in fig. 2; but the principle of its performance will be more easily understood by reference to the sectional diagram in fig. 3, where C C is the condensing lens, H H the mirror which receives the sun's light, and reflects it in the direction of the axis of the tube. This mirror turns on a hinge, by which it may be inclined at any desired angle to the axis of the tube; and a provision is also made by which it can be turned round the axis, so that its plane may be presented in any desired direction to the sun: a smaller condensing lens is interposed, upon which the rays, converging from C C, are received, and by which, with increased convergence, they are projected upon the opening O O in the slider S S, in which the object is mounted.

The tube in which the slider S S is inserted, and which carries the smaller condenser, slides within another tube, in the end of which the greater condenser C C is set. By this arrangement, the section of the cone of light, which falls upon the opening O O, may be varied, according to the magnitude of the object.

The amplifying lens, or lenses, L L, are conveniently mounted in a tube, which can be moved within certain limits to or from the object, so as to accommodate the focus to the position of the screen I I, upon which the image is projected.

After these explanations, the reader will have no difficulty in comprehending the instrument, as shown in perspective in fig. 2.

A board, A A B B, is pierced by a large circular aperture, the diameter of which is a little greater than that of the larger condensing lens; a square brass plate, *a a b b*, to which the microscope is attached, is screwed upon this board in such a position, that the condensing lens shall be concentric with the hole in it, and, consequently, that the axis of the instrument shall be at right angles to the board.

The plane mirror M, by which the light of the sun is reflected along the axis of the instrument, is mounted outside the board A A B B, moving on a hinge, as already described; and screws are provided at C C′, by means of which its inclination to the axis of the microscope can be varied at pleasure, and also by which it can be turned round the axis, the screw which governs its motion moving on the circular opening S D. By these means, whatever

be the position of the sun in the heavens, such a position can always be given to the plane of the mirror, that the light may be reflected along the axis of the microscope.

The great condensing lens is set in the larger end of the conical tube T, and the lesser in the end of the cylindrical tube T′; the latter tube being moved within the former by an adjusting screw, which appears at its side. By the second condensing lens, the light is collected upon the opening in the slide, which is held between two plates N, pressed together by spiral springs.

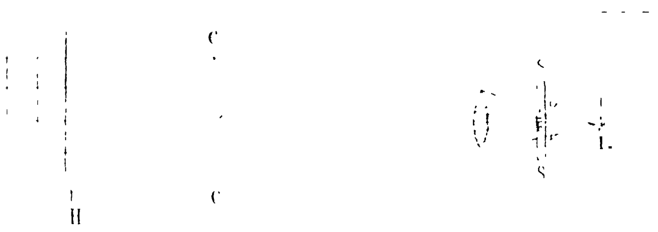
The tube T′ consists of two parts, one moving within the other, like those of the telescope.

The amplifying lenses are mounted in a brass ring, K, carried by the upright piece, I, so that its optical axis shall coincide with that of the illuminating apparatus. This optical part can be moved to and from the object, by means of a rack and pinion, F, attached to the piece H, which slides in the box G.

The structure and principle of the instrument being understood, it only remains to explain the method of using it.

11. The room in which the operations are conducted should have sufficient depth to allow the space between the microscope and the screen, which is necessary for the formation of an image of the required magnitude. This space will vary with the magnifying power required, but in general 10 or 12 feet beyond the nozzle of the instrument is sufficient. The room should be rendered as dark as possible, to give effect to the image, which, however well

Fig. 3.



illuminated, is always incomparably less bright than would be objects receiving the light of day. The window-shutters should therefore be carefully closed, and all the interstices between them stopped. If the room be provided with window-curtains, they should be let down and carefully drawn. In a word, every means should be adopted to exclude all light, except that which may enter through the microscope.

An opening being provided in a convenient position in one of the window-shutters, corresponding in magnitude with the aperture in the board AA BB, the latter is screwed upon the window-shutter, so that the two openings shall coincide. The mirror M will then be outside the window-shutter, while the instrument and its appendages will be inside. The window selected should, of course, be one having such an exposure that the sun's rays can be reflected by the mirror in the direction of the axis of the tube.

12. To adjust the instrument, remove the piece N, which supports the slider, so that the light may pass unobstructed to the amplifying lens. By varying the position of the reflector M, by means of the milled heads C C′, a position will be found in which a uniformly illuminated disc will appear on the screen; this disc may be rendered more clear and distinct by adjusting the instrument by means of the rack and pinion attached to the tube.

When these preliminary adjustments are made, the piece N is replaced, and an object inserted in it; the instrument being then more exactly focussed, a distinct image of the object, upon a large scale, will be seen on the screen.

The management of the instrument will vary with the nature of the object. If it be a very transparent one, a strong light thrown upon it would cause it almost to disappear. The light, therefore, in such case, must be so regulated as to produce the image in the most favourable manner, which may always easily be accomplished by moving the tube T′ in and out of the tube T, until the desired result is obtained.

When the experiments are continued for any considerable interval, it will be necessary, from time to time, to accommodate the reflector M to the shifting position of the sun, which may always be done by the milled-heads C C′. This adjustment, however, might be superseded by mounting the mirror M upon an apparatus called a Heliostat, the effect of which is, to make the mirror move with the sun, by means of clock-work. Such an apparatus, however, is expensive, and the adjustment above described is attended with no great inconvenience or difficulty.

13. The substitution of the oxy-hydrogen, or electric light, for the sun in this most instructive instrument, renders those who use it, however, altogether independent of the sun, so that it can be used for a night as well as a day exhibition. Since the method of applying to it the electric light has been already described very fully in our Tract upon the Magic Lantern, the explanation need not be reproduced here.

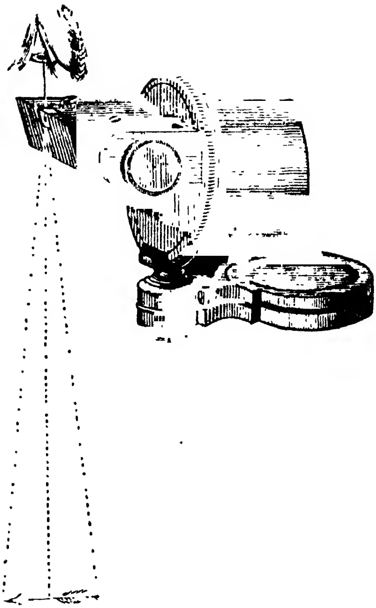


Fig. 8.

THE CAMERA LUCIDA.

1. Origin of the name.—2. Its use.—3. Method of applying it.—4. Explanation of its principle.—5. Precautions in using it.—6. Methods of correcting the inversion of the object.—7. Amici's Camera.—8. Magnitude of the picture.—9. Application of Camera to the microscope.

1. THIS instrument, which takes its name by contrast from the camera-obscura, is one of the many gifts of the genius of Dr. Wollaston to the arts.

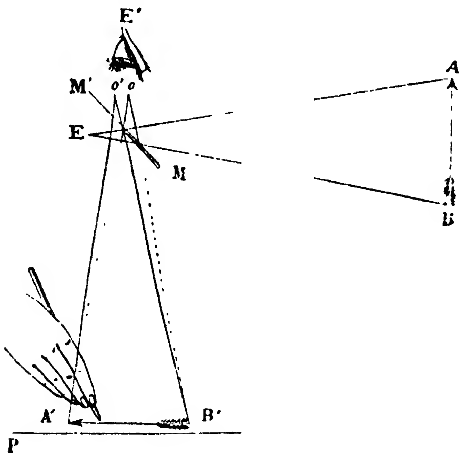
2. Like the camera-obscura, its chief, though not its only use, is to enable a draughtsman by the mere process of tracing, to make a drawing of an object.

3. The observer places upon its table, a sheet of drawing paper, and the instrument being placed level with his eye, he

looks into it, and sees the object to which it is directed, and at the same time sees, in the same direction, the sheet of paper which is upon his table, so that in fact, the object to be drawn, or its optical image, is seen projected and depicted on the paper. If he take in his hand a pencil, and direct it to the paper, as if he were about to write or draw with it, he will see his own hand and the pencil directed to the paper upon which the object is already optically delineated ; and he will consequently be able, with the utmost facility and precision, to conduct the point of the pencil over the outlines of the object and those of every part of it, so as to make as correct a drawing of it as could be made by the process of tracing, in which a picture, placed under semi-transparent paper is traced by a pencil moving over its outlines.

4. To present the principle of this contrivance under its most simple point of view, let A B, fig. 1, be an object which would be

Fig. 1.



seen by the eye of an observer at E, under the visual angle A E B, and let P P, be a sheet of paper, placed upon a horizontal table before the observer. Now let a piece of plane glass, one half of which is silvered on the lower surface, be placed at an angle of 45°, with the direction in which the object A B is seen, so as to intercept the view of it from the eye at E ; the rays of A E and B E, which encounter the silvered part of the glass, and which previously proceeded to E, will now be reflected to o, still, however, retaining the same divergence, so that they will enter the eye E′ of the observer,

supposed to look downwards at *o*, as if they had proceeded from A′ B′. In this manner the observer, looking from E′ towards the table, will see an image of the object at A′ B′, the point A′ of the image which corresponds with the top of the object being nearest to him, and the point B′, which corresponds with the bottom, being farthest from him; so that, in effect, the image will appear inverted.

Now suppose two lines, A′ *o*′ and B′ *o*′, drawn from the extremities of the image A′ B′, to a point *o*′ very near to *o*, and so as to pass through that part of the glass M M′ which is not silvered. An eye looking from *o*′ would then see the part of the paper upon which the image A′ B′ is projected, and would also see a pencil held in the hand of the draughtsman directed to the paper.

If the distance between the points *o* and *o*′ be less than the diameter of the pupil of the eye, the observer looking down from E′ will see at the same time, and in the same position, the image A′ B′ and the part of the paper corresponding with it,—for he will see the image by the rays which converge to *o*, and the paper by those which converge to *o*′; the effect, in short, will be that he will see the image as if it were actually projected upon the paper.

If the eye be advanced towards the mirror, so far as to cause the limiting ray A′ *o* to graze the lower edge of the pupil, the paper will be altogether intercepted by the silvered part of the glass M M′, and the observer, though still seeing the image of A B reflected in the glass, will no longer see it on the paper, and for the same reason, he will see neither his hand nor the pencil, and he cannot of course make the drawing.

If, on the contrary, the eye be moved from the glass so far as to cause the limiting ray A′ *o* to graze the upper edge of the pupil, the image of A B reflected from M M′ will altogether disappear, and nothing but the hand and the pencil will be seen, these last being visible through the unsilvered part of the glass.

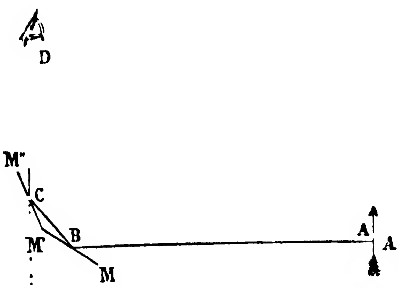
5. It is evident, therefore, that in order to enable the eye to see the entire image projected on the paper, it must be held in such a position, that while the limiting ray B′ *o*′, shall pass within the lower edge of the pupil, the limiting ray A′ *o* shall pass within its upper edge. That this may take place, it is necessary that the distance between the points *o* and *o*′ shall not exceed the diameter of the pupil, and that the eye be steadily held, so that *o* and *o*′ shall be both within the pupil.

Since the average diameter of the pupil is two-tenths of an inch, it follows that the distance between the points *o* and *o*′ should not exceed that limit, and that any displacement of the head which would displace the eye through the space of two-tenths of an inch, would remove from view the pencil or image, partly or wholly.

It will be easy from these considerations to appreciate the difficulty of using this instrument, and the necessity for practice and patience from those who expect to acquire facility and expertness in its management.

6. The inversion of the object produced by the reflector M M′, being inconvenient, a modification of the instrument was contrived, which gives an erect image; this is accomplished by the easy and obvious expedient of subjecting the rays proceeding from the object to two successive reflections, the first of which, as described above, would give an inverted image, which being itself inverted by the second, gives an erect image of the object.

This is effected by two plane reflecting surfaces M M′ and M′ M″, fig. 2, placed at an angle with each other of 135°; the one M M′ being inclined at $22\frac{1}{2}°$, with a horizontal line, and the other at the same angle with the vertical line. A ray A B, coming horizontally from the object, will fall upon M M′ at an angle of $22\frac{1}{2}°$, and being reflected at the same angle, will fall upon M′ M″, still at the same angle, being reflected from it, in the vertical direction, C D. An object A, after the second reflection, will therefore be seen erect upon a level surface, before a draughtsman who stands with his



face towards A, and stooping over the reflector M′ M″, sees the image of A in it.

In some forms of the instrument, the reflections are made by a prism, on the principle explained in "Optical Images," (24.) Thus if one reflection only be used, a rectangular prism is applied,

as shown in fig. 3, the ray A B from the object entering the face of the prism perpendicularly, and being reflected at B to the eye at C.

If two reflections be used, a quadrangular prism, having two

Fig. 3.

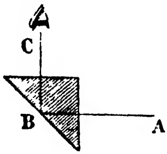
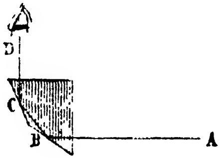


Fig. 4.



angles of 67½°, one right angle, and one of 135°, is applied, as shown in fig. 4. The course of the ray from the object to the eye being A B C D.

In the preceding cases, we have supposed the observer to see the object by reflection, and the paper and pencil directly; but it is evident that the conditions may as easily be reversed, so that the object may be seen directly, and the paper and the pencil by reflection. Thus we may suppose the plane mirror M M′ in fig. 1, to be silvered in the upper instead of the lower surface, and the observer looking from E horizontally to see the object directly through the unsilvered part, while he sees the paper and pencil by the reflection from the silvered part.

This method is in many cases found more convenient than that first described.

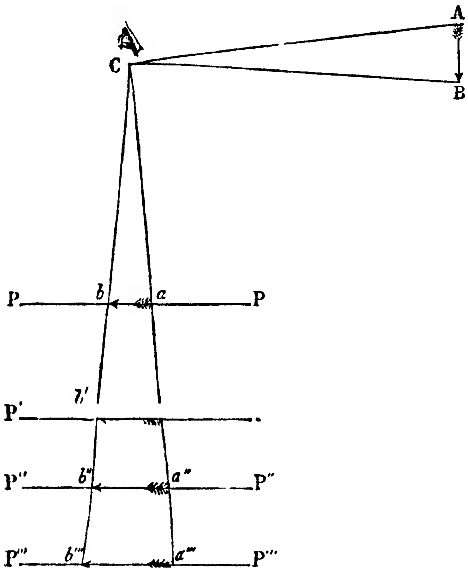
7. In some forms of the instrument, the observer looks at the object through a small hole made in a plane reflector, placed at an angle of 45° in the direction of the paper; the diameter of the hole being less than that of the pupil. In this case, while the object is seen directly through the hole, the paper and pencil are seen by reflection from the surface of the reflector surrounding the hole; this is the form of the camera-lucida applied to the microscope by Professor Amici.

8. Whatever be the form of the camera, the visual magnitude of the image projected on the paper as seen by the eye applied to the instrument, is the same as the visual magnitude of the object seen directly, and this will be the case at whatever distance from the camera the paper may be placed. It follows from this, that the actual magnitude of the picture projected on the paper will be greater or less according to the distance of the paper from the camera, and that consequently the observer, by regulating the

distance of the paper, can obtain a picture of the object on any scale he may desire.

To render this more apparent, let C, fig. 5, be the place of the

Fig. 5.



camera, and A B the object, whose visual angle will therefore be A C B. If the paper be placed at P P, the lines C a and C b, drawn to the extremities of the image upon it, will make the angle a C b equal to A C B, so that the visual angle of the image a b, will be equal to that of the object A B.

If the paper be now removed to P' P', the visual lines C a, C b, continued to it at a' b', will still be those which mark the extremities of the image, whose visual magnitude will therefore be measured by the same angle. But the space which the image covers on the paper at P' P', or what is the same, the actual length of the optical picture on the paper, will be greater than at P P, in the proportion of a' b' to a b, or what is the same, to the distance of P' P' to that of P P from C.

In the same manner it will appear, that if the paper be successively moved to greater distances, such as P'' P'', and P''' P''', the

picture will be magnified in its linear dimensions, in the exact proportion in which its distance from the camera is increased.

9. One of the most recent and beautiful applications of the camera-lucida, is its adaptation to the compound microscope, by means of which, details and lineaments of objects, so minute as to escape ordinary vision, are depicted with a precision and fidelity only surpassed by the results of photography.

The instrument is fixed upon the eye-piece of the microscope, in such a manner, that while the observer looks directly through the eye-glass at the object, he sees the paper and pencil by reflection, the latter being placed upon the table before him. Supposing the axis of the microscope to be horizontal, the paper and pencil will be reflected from a plane mirror placed at an angle of 45° with the vertical, the reflecting side being turned downwards.

The instrument may be so arranged, that the paper may be seen directly, and the object by reflection. In this case, the mirror is also placed at 45° with the vertical, but the reflecting side is presented upwards. The rays, proceeding through the eye-glass from the object, are reflected upwards and received by the eye of the observer, which, looking downwards, views the paper directly.

In figs. 6 and 7, is shown the arrangement by which the observer O, views the object directly through a small hole in the oblique reflector, which is fixed upon the eye-piece, while he sees the paper and pencil by two reflections, the first from the back of the prism P, and the second from the oblique reflector M m. The effect is to project the image of the object seen in the microscope V, upon the image of the paper seen in the reflector M m.

Fig. 6.

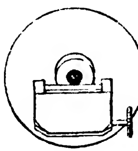
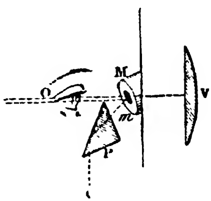


Fig. 7.



The prism P is interposed in this case to render the image of the hand and pencil erect; a front view of the prism and eye-piece is shown in fig. 6, and a side view in fig. 7.

In fig. 8, an arrangement is shown by which the object is seen by reflection, and the paper directly.

In this case the rays issuing from the eye-piece of the microscope are reflected twice successively from the two sides of the prism, which are inclined to each other at an angle of 135°, as explained in (6).

According to what has been explained in (8), the observer can vary the magnitude of the picture on the paper by varying the distance of the paper from the prism, without varying the magnifying power of the microscope; and in this way he can make a tracing of the object on any desired scale.

THE MAGIC LANTERN.

1. Optical principle of the instrument.—2. Its most common form.—3. Magnifying power.—4. Precautions to be taken in the use of the instrument.—5. Pictures on the sliders.—6. Opaque screen.—7. Transparent screen.—8. Phantasmagoria—method of producing it.—9. Exhibition with two lanterns.—10. Curious optical effects.—11. Dissolving views.—12. Application of the lantern to the purposes of instruction—in history and chronology.—13. In geology.—14. In astronomy.—15. Use of solar system.—16. Great utility of the lantern for this purpose.—17. Views of the stars.—18. Nebulæ and clusters.—19. Practical example of the utility of this instruction.—20. Oxyhydrogen lantern.—21. Application of electric light to the lantern.

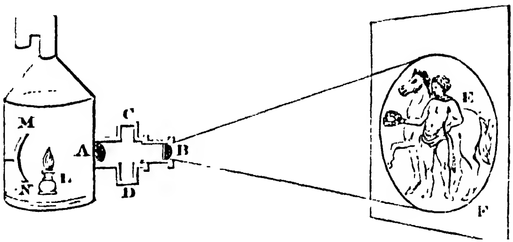
1. The magic lantern is an optical instrument adapted for exhibiting pictures, painted on glass in transparent colours, on a large scale by means of magnifying lenses.

It has been shown (see "Optical Images") that when a picture, or other object, is placed in front of a convex lens, at a distance from it somewhat greater than its focal length, such picture or object

will be reproduced upon a screen, placed at a certain distance behind the lens, that distance being greater the nearer the picture in front of the lens is to its principal focus. This is the principle upon which the magic lantern is constructed.

2. It varies in form and arrangement, according to its price and the circumstances under which it is used, but in general consists of a dark lantern fig. 1, within which a strong lamp L is placed,

Fig. 1.



having a bent chimney at the top, to allow the smoke and heated air to escape, while the light is intercepted. In front of the lamp, and on a level with its flame, a tube is inserted, in which a large convex lens A is fixed, by means of which the light of the lamp is condensed upon the picture placed opposite the lens A, by sliding it through a groove, C D. From this mode of fixing the picture, the latter has generally been called a "slider." In the tube thus projecting from the lantern, another tube is fitted sliding in it, as one tube of an opera-glass slides in the other. At the end of this second tube a convex lens B is set, and the tube is so adjusted, that the distance of B from the picture shall be a little greater than the focal length of the lens B. A large screen F, made of white canvas, which is much improved by covering it with paper, is then placed at a distance from B, and at right angles to the axis of the lens. By properly adjusting the tube B, and the distance of the screen F, the picture upon the slider in C D will be reproduced at E upon the screen, on an enlarged scale.

It must be observed, however, that as the picture will be inverted, with relation to the object, it will be necessary to turn the slider in C D upside down, in order to have the picture on the screen in its proper position.

To increase the illumination of the slider, a concave reflector M N is usually placed behind the lamp, by which the light projected upon the lens A is increased. A better effect, however, may be produced by simply bending a sheet of white paper or paste board round the inside surface of the lantern.

3. With the same lantern, and the same slider, a picture of any desired magnitude can be produced. To increase the picture, it is only necessary to push in the lens B, so as to bring it closer to the slider, and to remove the screen F to a greater distance. But it must be remembered, that every attempt to enlarge the picture will not only be attended with greater indistinctness, owing to spherical aberration, and more appearance of colours at the edges of the figures, owing to chromatic aberration, but also the brightness of the picture will be greatly diminished, since it is evident that the greater the surface over which the light by which the slider is illuminated is diffused, the more faint, in the same proportion, will the picture on such surface be; and, since the magnitude of such surface increases in the same proportion as the square of its linear dimensions, it follows that when the picture has double the height or width, it will be four times less bright. (See Tract on "Optical Images.")

4. The body of the lantern should be large, so that it may not become inconveniently heated. The best oil should be burnt in the lamp, so as to diminish the smoke and disagreeable odour. The glass chimney of the lamp should be made as high as possible, and the wick should be of large calibre.

5. The pictures on the sliders should be as large as possible, in order to ensure sufficient illumination on the screen. With a given magnitude of picture on the screen, and a given force of lamp, the illumination will be proportional to the magnitude of the slider. If a small slider be used to produce a picture on the screen of a given magnitude, the confusion arising from both kinds of aberration will be greater than if a larger one were used.

6. There are two ways of exhibiting the pictures on a screen: in one, the lantern is placed in front of the screen, with the spectators; in that case the picture is seen by the light reflected from the screen, after having been projected upon it by the lantern.

Care should therefore be taken that no light shall penetrate through the screen, since all such light would be lost, and the picture on the screen would be proportionally more faint. A screen composed of muslin, or any other textile fabric, would in such case be defective, inasmuch as more or less of the light would penetrate it. The best sort of screen is one made of strong white paper, pasted on canvas, and stretched on a frame, as canvas is in a picture.

7. When the magic lantern is used for purposes of amusement, rather than those of instruction, it is generally found desirable to use a semi-transparent screen, the lantern being

mounted on one side of the screen, and the spectators placed on the other, as shown in fig. 2 (p. 193). In this case, the screen should be made of white muslin or fine calico stretched upon a frame, its transparency being increased by wetting it well with water. In some cases the muslin is prepared with wax or oil, which may be convenient to save the trouble of wetting it, but which in other respects does not answer the purpose better.

8. When the pictures are produced through a transparent screen, the exhibitor being concealed from the spectators, may make them vary in magnitude: first gradually increasing, and then gradually diminishing. This is accomplished by moving the lantern gradually and alternately from and towards the screen, varying the focus during the motion, so as to render the picture upon the screen always distinct.

Let us suppose for example, that the nozzle of the lantern is first placed in actual contact with the screen. The picture on the screen will then be exceedingly small, and the spectators, to whom the screen is invisible, will imagine the object to be at a great distance. Let the exhibitor then move back the lantern slowly from the screen, keeping the focus constantly adjusted, the picture on the screen will then be gradually enlarged, and the impression produced on the spectators will be that its increased magnitude is produced by the gradual approach of the object towards them; and so complete is this delusion, that the rapid increase of magnitude of the picture actually startles even persons who are most familiar with the optical causes which produce the effect. It sometimes appears as if the object would approach so as to come in actual collision with the spectator.

When the object seems thus to be brought near the spectator, it is made to retire gradually by moving the lantern towards the screen, the effect being produced by the gradual diminution of the image upon the screen, and this is continued until the nozzle of the lantern coming again in contact with the screen, the object seems again to be lost in the distance, its magnitude being reduced to a mere point. The exhibitor seizes this moment to change the picture, displacing one slider by the introduction of another, a manœuvre which, when adroitly performed, will escape the notice of the spectators. The new picture is then exhibited in the same way.

Effects of this kind have been denominated "phantasmagoria," from the Greek words φαντασμα (phantasma), *a spectre*, and αγοραομαι (agoraomai), *I meet*.

9. Interesting and amusing effects are produced by placing two lanterns of equal power, so as to throw pictures of precisely equal magnitude on the same part of the same screen. A sliding cover

is placed in front of the nozzle of each of the lanterns, and these are moved simultaneously in such a manner, that when the nozzle of one lantern is completely opened, that of the other is completely closed, so that, according as the former is gradually closed, the latter is gradually opened.

10. To illustrate this class of effects, which always create an agreeable surprise, let us suppose that two sliders are placed in the lanterns, one representing a landscape by day, and the other representing precisely the same landscape by night, and let the nozzle of that which contains the day landscape be opened, the other being closed: the picture on the screen will then represent the day landscape. If the covers of the nozzles be now slowly moved, so that that of the lantern which shows the day landscape shall be gradually closed, and that of the other shall be gradually opened, the effect on the screen will be that the day-light will gradually decline, the view assuming, by slow degrees, the appearance of approaching night. This gradual change will go on, until the nozzle of the lantern containing the day picture has been completely closed, and that containing the night picture completely opened, when the change from day to night will be accomplished, the picture on the screen being then a night landscape.

An infinite variety of amusing effects of other kinds are contrived by accessories combined with such pictures. Thus, for example, a view, exhibiting a landscape in bright sunshine, becomes gradually clouded and obscure, and snow begins visibly to fall; the darkness increases, night comes on, the moon rises, illuminating the landscape, which now appears covered with snow. The wheel of a mill, which was moved by a stream, which seemed flowing in the sunshine, is now at rest, loaded with snow and icicles; the stream no longer flows, but is frozen.

All these effects are produced by two or more lanterns, the mill-wheel is a little metal-wheel attached to that part of the slider on which the mill is delineated, and kept in motion by wheel-work impelled by the hand of the exhibitor. The fall of snow is produced by a sheet of blackened paper, pierced with a multitude of little holes, and moved before the lamp by means of rollers at the top and bottom; the light passing through the holes forms white spots, which are projected on the screen, and which appear to fall like snow-flakes. The clouds pass over the sun or moon, or move from them so as to cover or unveil them, by the motion of a second slider behind the first.

Another class of appearances is produced by one of the exhibitors managing with address a small supplemental lantern. Thus, for example, the picture of a castle, with portcullis and

drawbridge, is exhibited; the portcullis rises, and a knight in armour issues from it on horseback, and crosses the drawbridge.

The opening of the portcullis is in this case produced by a moveable plate attached to the slider representing the castle, and the figure of the knight is produced by means of a second lantern, so skilfully managed as to throw the image of the knight upon the screen, and to move it, so as to make it appear to cross the drawbridge.

11. The optical effect produced by two lanterns working together, called dissolving-views, with which the public has been rendered familiar, at several of the public institutions in London, depends on the alternate opening and closing of the nozzles of two lanterns, in the manner already described, the mistiness and confusion which is exhibited in the gradual disappearance of the one view, and the gradual appearance of the other, arises from the circumstance of the nozzles of both lanterns being partially open at the same moment, so that both views, faintly illuminated, are projected upon the screen at the same time. The mixture of their outline and colours produces the mistiness and confusion, with which all spectators of such exhibitions are familiar. According as the nozzle of the lantern which contains the disappearing view, is more and more closed, and that which contains the appearing view more and more open, the latter becomes more and more distinct, and becomes perfectly so, when the one lantern is completely closed, and the other is completely opened.

12. These, and innumerable other optical effects, are limited in their object to the mere purpose of amusement. Without rejecting such lighter use of the lantern, its possessors should not, however, forget that it is capable of infinitely more important uses. It may be made extremely useful in impressing upon the minds of young persons the most important events and epochs in history and chronology, by the exhibition of series of portraits and scenes accompanied by observations and comments upon them proceeding from an intelligent instructor. Its use in conveying general notions of natural history is well known. Paintings of the various classes of animals and plants are executed sufficiently well for the purposes of such instruction, and sold by the opticians at a very moderate price. The use of the lantern in this department might be considerably extended, if similar paintings of insects and animalcules, on a magnified scale, could be obtained; these being still more enlarged by the lantern, many of the effects of the solar microscope might be exhibited, and much instruction imparted.

13. In the same manner, the first notions of geology might be conveyed by sections of the strata properly painted on the

sliders. It is obvious also that the fossil animals could be very advantageously presented in this way.

14. But of all the departments of instruction for young persons, that to which the magic lantern lends itself most happily is astronomy; and here the artists have already prepared admirable sets of sliders, which can be obtained at moderate prices, and convey, in a most pleasing manner, most important instruction. Thus, the annual and diurnal motion of the earth, with the vicissitudes of day and night, and the succession of the seasons, are executed by means of a slider provided with mechanical expedients for producing the several effects. In the same manner, sliders are adapted to show the effects of the sun and moon in producing the tides of the ocean; the motions of the planets round the sun; solar and lunar eclipses; the motions of comets, with the development of their tails, and in a word all the principal motions of the bodies composing the solar system.

15. A class of astronomical objects, which would supply highly interesting and instructive subjects of optical exhibition with the lantern, would be telescopic views of the sun, moon, and planets. The spots on the sun well delineated, as they might be, the remarkable lineaments of the moon, showing so conspicuously the inequalities of its surface, the peculiar appearances exhibited by the disc of Mars, on which the polar snow is visible, and the outlines of land and water faintly apparent, the atmospheres of Jupiter and Saturn, stratified by their atmospheric currents, so as to produce belts, the triple ring of Saturn, the motions of the satellites of Jupiter and Saturn, showing their eclipses, are severally phenomena which might easily be exhibited with the lantern. Some of these have been already attempted by the opticians, but in a manner that had better have been left alone. The telescopic views of the planets given upon the common sliders are worse than worthless, since they produce most erroneous notions. The view of the moon usually given is less objectionable; nevertheless, nothing would be more easy than to get proper sliders painted from good originals, which are easily obtained. Excellent telescopic views of Mars, Jupiter, and Saturn have been reproduced in my work on astronomy from the original drawings of Mädler, Herschel, and other authorities. I have given them on a scale such that they could be transferred to sliders without difficulty; Saturn with his rings I have also given from the original drawings of the most recent observers.

Various views might be given of different parts of the moon's surface, and of the solar spots; these I have also given on a proper scale from the originals of Pastorff, Mädler, Herschel, and others. Comets, with their extraordinary changes of form

and appearance, would also form an interesting series of astronomical objects.

16. Those who have not practically tried the effects of such a mode of instruction can with difficulty imagine the extent and variety of information that may be imparted by it, the facility with which it is acquired, and the tenacity with which it is retained. For the acquisition and retention of knowledge there is no organ like the eye. The most able and clear-headed instructor, using his best exertions by oral instruction, will never impart so clear a notion of the motions of the heavenly bodies, or their telescopic appearance, as that which may be obtained by the ocular, even though silent lessons of the magic lantern. But if the exhibition produced by that instrument be accompanied by proper oral comment and exposition, there are no means of instruction with which I am acquainted, suitable to young persons, that can approach to it.

17. Passing beyond the solar system, the starry firmament supplies an endless series of objects for optical exhibition with the lantern. The pupil can with the greatest facility be rendered familiar with the constellations, and the teacher may make for himself the sliders. Let him provide three or four pins of different thicknesses, and let him mark upon thick paper or pasteboard the arrangement of the stars in each principal constellation, which he can easily do by the aid of any celestial maps, and for this purpose I would recommend Professor de Morgan's "Guide to the Stars." Having thus marked out the constellations, let him pierce, with the thickest of the pins, holes corresponding with the places of the stars of the first magnitude. In the same manner, holes for stars of the second magnitude will be pierced by the next sized pin, and so on. The paper thus pierced being pasted on slips of glass, may be used as sliders.

18. It is scarcely necessary to add, that telescopic views of the nebulæ and stellar clusters may be produced and applied in the same manner.

19. In recommending thus emphatically the magic lantern as an instrument of instruction for the young, I speak from practical knowledge of its effects, having applied it in the case of my own children, and obtained all the results which I have here indicated.

20. For family and school purposes, a good lamp is the most convenient means of illuminating the sliders; but where exhibitions are produced before larger and adult audiences, other and more effectual means of illumination are resorted to. For several years, the lanterns by which dissolving-views, and other effects, have been produced at the public exhibitions in London, have

been illuminated by the oxy-hydrogen light. The manner in which this illumination is produced will be explained more fully in another part of the MUSEUM. Meanwhile, we may briefly state here, that the light proceeds from a ball or cylinder of lime, which is rendered incandescent, or white-hot, by the flame of a blow-pipe, from which a mixture of oxygen and hydrogen gases, in the proportion in which these gases produce water, issues.

It might be imagined that the light produced by a piece of solid matter like lime, however intensely heated, could never be brilliant enough to produce a strong illumination; nevertheless, the light radiated from the lime in this case was the most intense artificial light which had ever been produced until the invention of another, which we shall presently notice.

In the oxy-hydrogen lanterns, the cylinder of lime is mounted, so as to occupy the place of the flame of the lamp in the axis of the lenses. The flame of the blow-pipe is projected upon that side of it which is presented towards the lenses, and since the lime, though it does not undergo combustion, is gradually wasted by the action of the flame, it is kept in slow revolution by clock-work, connected with the axis upon which it is supported, so as to present to the flame successively different parts of its surface.

21. This method of illumination, though still continued, is greatly surpassed in splendour by that of the electric light, which has recently been applied to the magic lantern by Mr. Dubosc, the successor of Mr. Soleil, the celebrated Paris optician.

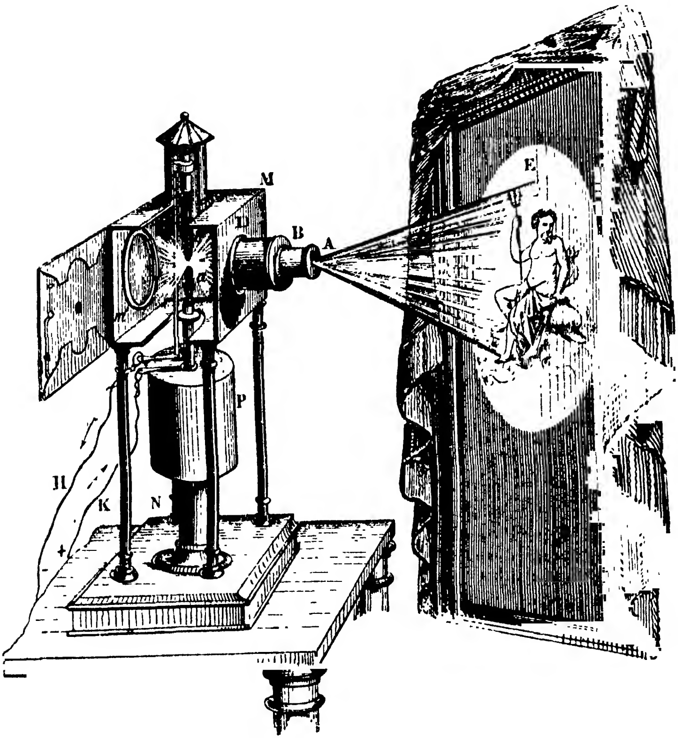
The electric light, which will be more fully described in another part of this series, is produced by bringing two pieces of charcoal, previously put in connection with the poles of a Voltaic battery, nearly into contact; the Voltaic current will then pass from one to the other, the ends of the charcoal thus nearly in contact becoming incandescent, and emitting the most brilliant artificial light which has ever yet been produced.

The method of mounting this illuminating apparatus in the lantern is shown in fig. 3.

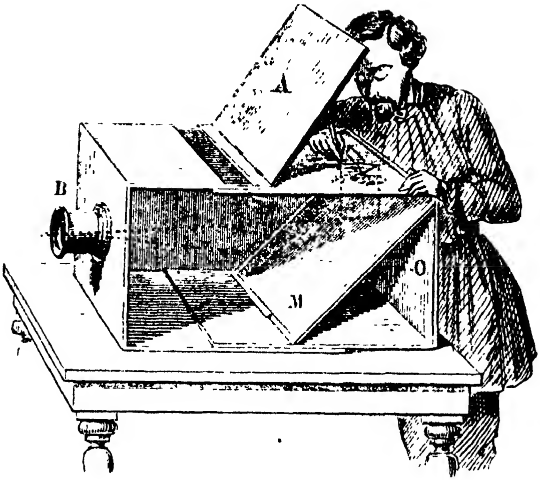
The wires H K, being connected with the poles of the battery, are attached to two pieces of metal, the negative wire H communicating with the upper pencil of charcoal *c*, and the positive wire K with the lower charcoal pencil *a*. The points of the pencils being nearly in contact, the light will be produced in the manner just explained.

Although the charcoal does not, properly speaking, undergo much combustion, it is gradually wasted, and when the points would thus become separated, the current would be suspended, and, therefore, the light would cease. To prevent this, and to maintain the illumination, an apparatus consisting of clock-

work is provided in the case P, by which the charcoal pencil *a* is kept nearly in contact with the pencil *c*. The clock-work is so constructed that its motion is governed by the current.



Mr. Dubosc has contrived the means by which a single electric light will serve to illuminate at the same time two lanterns, placed side by side for exhibition. This is accomplished by placing the light between two reflectors, so inclined that each reflects it in the direction of the axis of one of the lanterns.



THE CAMERA OBSCURA.*

1.—Principle of the instrument.—2. Its inventor.—3. Method of mounting it.—4. Application of the prism to it.—5. Mounting a camera with prism.—6. Portable camera.—7. Form of camera adapted to photography.

1. THIS is an instrument of extensive utility in the arts of design; by it the process of drawing is reduced to that of mere tracing, and its use has of late been greatly extended by its application in the art of photography.

We have already explained, in our Tract upon "Optical Images," that if a convex lens, or any equivalent optical combination, be presented to a distant object, such as a landscape, an inverted image of that object, with its proper outline and colours, will be produced at the principal focus of the lens. Let us suppose, for example, that the window-shutters of a chamber being closed, so as to exclude the light, a hole be made in them, in which a convex lens is inserted: let a screen made of white paper be then placed at a distance from the lens, equal to its focal

* Two Latin words, signifying "a dark chamber."

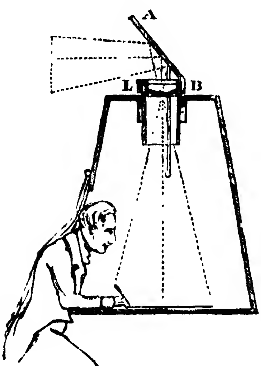
length, and at right angles to its axis; a small picture will be seen upon the screen, representing the view facing the window to which the axis of the lens is directed; this picture will be delineated in its proper colours, and all moving objects, such as carriages or pedestrians, the smoke from the chimneys, and the clouds upon the sky, will be seen moving upon it with their proper motions. The picture, however, will be inverted, both vertically and laterally, the sky being below and the ground above; trees and buildings will have their tops downwards, vehicles will move with their wheels, and pedestrians with their feet, upwards, objects on the right of the landscape will be on the left of the picture, and *vice versâ*, and all motions will be reversed in direction; objects moving to the left appearing to move to the right, and those which fall, appearing to rise.

2. This remarkable optical phenomenon was discovered in about the middle of the sixteenth century, by Baptista-Porta, a Neapolitan philosopher, and it was not long before it assumed a variety of forms, more or less useful; the name *Camera-Obscura* was given to it from the circumstances explained above.

3. A great variety of forms have been given to this instrument, varying according to the circumstances under which it is applied. One of the most simple of these is shown in fig. 1.

The lens, L, is inserted in an opening in the top of a rectangular box, the height of which is made to correspond nearly with its focal length; the bottom of the box is placed at a convenient height, to serve the purpose of a desk or table for the draughtsman; a sheet of drawing paper being placed upon it, will receive the optical picture of such distant objects as may be found in the direction of the axis of the lens. The lens is set in a tube, which slides in the opening made in the box, so that by moving it more or less upwards or downwards, the instrument may be brought into focus, and a distinct picture produced upon the paper. An opening is made in the box, at that side of it towards which the bottom of the picture is turned; the draughtsman introducing through this opening the upper part of his person, lets fall over him a curtain, suspended from the upper edge of the opening, so as to exclude all light from the box, save that which proceeds from the lens at the

Fig. 1.

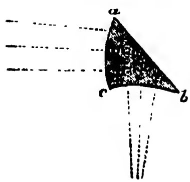


top. Thus placed, the draughtsman can trace the outlines of the picture.

But in the case here supposed, the axis of the lens being vertical, the picture would be that of the firmament. To obtain a picture of any part of the surrounding landscape, a plane mirror, A B, is fixed upon a hinge at B, and is regulated in its position by a handle which descends into the box, so that the draughtsman can give it any desired inclination. The effect of this mirror is indicated in the figure by the rays, which, falling upon it, are reflected downwards to the lens. It will be evident, from what has been already explained in our Tract upon "Optical Images," that when this reflector is properly adjusted, a picture of the landscape before it will be reflected towards the lens L B, and by it projected upon the desk of the draughtsman.

4. The oblique mirror A B, and the lens L, are sometimes replaced with advantage by a prism, such as that represented in fig. 2. The face, *a c*, of this prism, at which the rays coming from the landscape enter, being convex, these rays are affected exactly as they would be if they entered the convex surface, of a lens; when they fall upon the plane surface, *a b*, of the prism, they will be reflected from it, according to what has been explained in "Optical Images" (24); thus reflected, they will fall upon the other side, *c b*, of the prism; this side is ground concave, but its concavity being less than the convexity of the side *a c*, the effect of the two sides upon the rays will be the same as that of a meniscus lens, one side of which has the convexity *a c*, and the other the concavity *b c*. In such a lens the convexity prevailing over the concavity, the effect will be that of a convex lens.

Fig. 2.



The curvatures of the two sides of the prism are so regulated that its focal length shall correspond with the height of the box.

5. One of the methods of mounting a camera constructed with such a prism, is shown in fig. 3. The prism is mounted in a case, upon a horizontal axis, and its inclination is regulated by milled heads, like the heads of screws, on the outside; the case on which it is mounted has an opening through which the rays proceeding from the landscape are admitted; and it can be turned round its vertical axis, so that the opening can be presented in any direction to the surrounding landscape. The apparatus is supported by a triangle, and the draughtsman is surrounded by a curtain, forming a tent, from which the light is sufficiently excluded. The height of the tent, relatively to the table, is of course regulated according to the focal length of the prism.

6. Another variety of mounting for cameras is shown in fig. 4 (p. 203). This, which is one of the most portable forms of the

instrument, consists of a rectangular case, composed of two parts, one of which slides within the other like a drawer; in one end is placed the lens B, in the other a plain mirror M, inclined at an angle

of 45° to the top of the box. Over this mirror is a lid A, movable on hinges, under which in the opening is set a square plate of ground glass; the lid A is provided with arrangements by which it can be fixed at any desired inclination to the plate of ground glass, so as to shade the latter from the light: sides are sometimes provided to exclude the lateral light; which may also be accomplished by throwing a dark-coloured cloth over the box.

The rays which produce the picture, entering through the lens B, fall upon the mirror M, by which they are reflected upwards, to the plate of ground glass N, on which they produce the picture. The instrument is brought into focus by drawing out the end O of the box, until the picture appears with sufficient distinctness on the glass N.

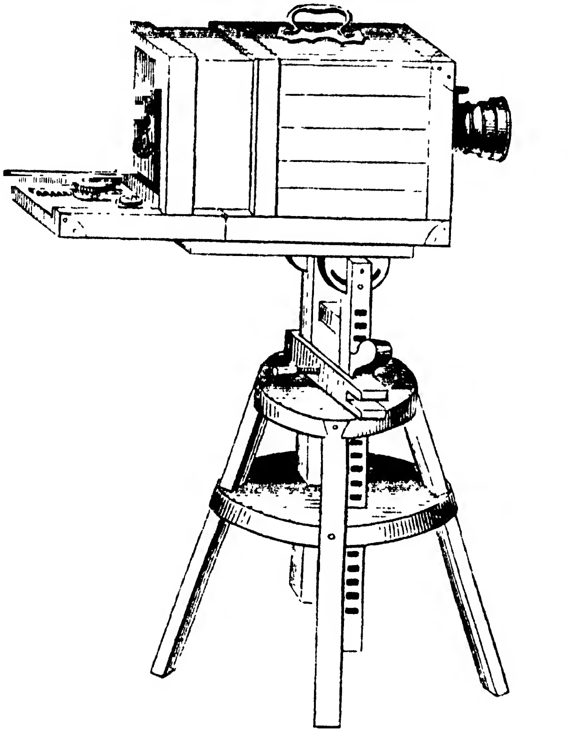
A leaf of tracing paper, being laid upon the glass, the picture is seen through it, so that it can be traced with facility and precision.

7. The form of camera usually employed for photography is represented in fig. 5; it is more simple in its construction than those already described, neither the prism nor the oblique mirror being used. The convex lens, or its optical equivalent, is set in a tube at one end of a square box, in which another square box slides like a drawer; in the end of this last, a plate of ground glass is let in, by means of grooves, so that it can be inserted and removed at pleasure; the instrument is brought into focus, either by sliding the one box within the other, or by a rack and pinion in the groove. When the picture is distinctly delineated upon the ground glass, the latter is drawn out, and a case containing the daguerreotype-plate or photographic-paper is inserted in its place. The paper or plate being, in the first instance, screened from the reception of the picture by a plate of metal or board let into a groove in front of it. When all is prepared for the operation, this screen is suddenly raised by the operator, and the picture allowed to fall upon the prepared paper or plate, and being allowed to continue there a certain number of seconds, more or less according to the brightness of the light, the screen is again suddenly let down, and the case containing the paper or plate is withdrawn from the groove, and the paper or plate is submitted to certain chemical processes by which the picture is brought out and rendered permanent.

The cameras which are adapted to photography require to be constructed with greater attention to optical precision than those which are used for other purposes in the arts. The focal length of the lenses being much shorter, optical expedients must be adopted for the removal of spherical aberration, which are not necessary in other applications of the instrument. The nature of

photography also renders it necessary that the lenses should be achromatic or nearly so. These conditions, as well as the chemical processes by which the daguerreotype-plate or photographic-paper

Fig. 5.



is prepared before receiving the picture, and treated after its reception, will be more fully explained in another Tract of this series, which will be expressly devoted to Photography.